PROMOTING ENERGY LITERACY THROUGH TEACHING STUDENTS ABOUT ENERGY USE AND BEHAVIOR

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Kathleen Halpin Thesis

Title:

Promoting Energy Literacy through Teaching Students about Energy Use and Behavior

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Research indicates that reductions in personal energy use can be effective in reducing a country's overall carbon dioxide emissions, potentially lessening the impacts of global climate change. However, the public is generally ill informed about energy use and the energy-saving behaviors that can lead to these reductions in emissions. As such, it is necessary to begin educating future citizens about the energy system and energy use in an effort to foster more energy literate students. This thesis uses existing research about energy literacy and misconceptions among students to create a cohesive curriculum unit to promote energy literacy through teaching about energy behaviors and use. High-quality lessons and activities about energy were found and compiled into a systems thinking curricular unit comprised of two activity cycles that address energy use, conservation, and efficiency, and the role students play in the larger energy system. Following the curriculum, a discussion connects each of the activities within the curriculum to systems thinking literature, educational theory, and the energy literacy research. Next, an exploration of where the activities within this curriculum guide can fit into various high school courses is included. Finally, curriculum writers were contacted in order to illuminate the barriers to distributing high-quality curricular units to science educators, and opportunities for further dissemination of research-based curriculums are presented.

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Thesis Literature Review

Introduction

As global climate change continues to be one of today's most difficult societal problems, researchers have examined the role of individual's actions as an important puzzle piece for reducing anthropogenic carbon dioxide emissions (IPCC, 2014). In response to Pacala & Socolow's *stabilization wedges,* Dietz et al. devised a *behavioral wedge* that could reduce national carbon emissions in the United States by 7.4 percent through 17 different household actions (Dietz et al., 2009; Pacala & Socolow, 2004). Gardner & Stern created the *Short List* of the most effective actions a household in the United States can take to reduce personal carbon dioxide emissions (2008). Attari et al. examined public perceptions of household energy use and conservation (2010). In each of these research endeavors, conclusions indicate that reductions in personal energy use can be effective in reducing a country's overall carbon dioxide emissions; however, the public is generally ill informed about energy use, conservation, and efficiency that can lead to these reductions (Attari et al., 2010; Dietz et al., 2009; Gardener & Stern, 2008).

In addition, surveys to measure energy-related awareness indicate a lack of knowledge about energy among the American Public (DeWaters & Powers, 2008; NOWCAST, 2005; NEETF, 2002; Gambro & Switzky, 1999; Farhar, 1996; Barrow & Morrisey, 1989). Indeed, a 2001 survey conducted by the National Environmental Education & Training Foundation (NEETF) found that only 12 percent of Americans could pass a basic energy knowledge quiz (DeWaters & Powers, 2008; NEETF, 2002). Therefore, it is necessary to begin educating future citizens about energy, energy use, and energy conservation and efficiency in an effort to foster more energy literate students. This thesis seeks to address existing research about energy literacy among students, and to explore common misconceptions that students and the larger public possess that may be preventing emission-reducing behaviors. Then, using this research about energy curriculums for promoting literacy and addressing energy misconceptions, a systems thinking curricular guide for high school students will be developed using the best quality resources from the internet. Finally, a discussion will follow that links this curriculum to the research on systems thinking, energy literacy, and educational theory to help educators see why this curriculum, among the arsenal of resources that are readily available, is a more ideal tool for fostering energy literate students.

Energy Learning Progressions

Before defining and exploring energy literacy, it is worthwhile to examine different learning progressions of energy concepts to better gauge the level of knowledge that students come into school with, and the ultimate learning goal for energy curriculums. Because *energy* is such a large and complicated topic, learning progressions have become a widely-used tool to measure student understanding of increasingly complex ideas that an energy literate student must understand. Learning progressions are characterized by a lower anchor, intermediate levels, and an upper anchor. The lower anchor characterizes what students know about the concept of energy upon entering school, and the upper anchor describes the knowledge, values, beliefs, and behaviors that we want students of energy to come away with. These structured learning progressions are attractive representations of the ongoing process of learning that builds more difficult concepts on more foundational and simplistic concepts (Jin & Anderson, 2012).

One learning progression that has emerged measures the reasonable expectations of student understanding of energy at different grade levels. Jin & Anderson investigated a learning progression focusing on the concept of energy specifically in regards to carbon-transforming processes. The learning progression they establish contains 4 Levels. Level 1 establishes simple cause-effect to explain how energy causes a change (i.e. something grows or moves). Level 2 also characterizes energy in a cause-effect relationship, but at this point students understand there are “hidden processes” and “physical constraints" that allow energy to cause change. In Level 3 students understand that the laws of conservation constrain energy processes, but cannot apply conservation laws, and in Level 4 students are able to use and apply these laws on conservation. In their study, Jin & Anderson found that among middle school students, 52 percent achieved a Level 2 understanding, 18 percent achieved a Level 3 understanding, and only 5 percent achieved a Level 4 understanding of energy. In high school students, 47 percent achieved a Level 2 understanding, 32 percent achieved a Level 3 understanding, and only 10 percent achieved a Level 4 understanding (Jin & Anderson, 2012). This study of learning progressions reveals that even high school students have a woefully underdeveloped understanding of energy concepts. Because of these underwhelming results, the authors discuss the necessity of quality instruction in energy concepts (Jin & Anderson, 2012).

Another learning progression was developed by the German National Education Standards whereby the lower anchor describes a student's ability to understand that energy comes in different forms and from different sources and the upper anchor is characterized by a complete understanding of energy forms, sources, transfer and transformation, degradation, and conservation (Sekretariat der Standigen Konferenz der Kultusminister der Lander in der Bundesrepublik Deutschland [KMK], 2005). This learning progression also has 4 Levels, with 4 minor levels within each major learning progression Level. In Level 1 students understand energy forms, in Level 2 students can identify that there is a relationship between these energy forms and physical processes (energy transfer), in Level 3 students grasp the concept of energy degradation, and in Level 4 students can understand energy conservation (Neumann et al., 2013). Neumann et al. tested the validity of this learning progression in grades 6, 8 and 10 and determined that while the general direction of the learning progression seems accurate, the Level distinctions are difficult lines to draw because students seem to learn many of these concepts in concert with each other. For example, students learn the concept of energy degradation alongside with the concept of energy transfer and transformation, which in this learning progression falls into 2 different Levels. Therefore, it may be worthwhile to further tease out the different levels into more specific learning goals (Neumann et al., 2013).

Defining Energy Literacy

In 1988 Lawrenz first argued that effective energy education should develop well-informed students with positive attitudes towards energy conservation (DeWaters & Powers, 2013; Lawrenz, 1988). Then, in 1989, Barrow & Morrisey defined an "energy literate individual" as someone who is both aware of, and has knowledge of, reasons for energy conservation, the need for alternatives to fossil fuels, and the impact of the energy system on the environment (Barrow & Morrisey, 1989). A more contemporary definition of energy literacy has been established by DeWaters et al. (2007). These authors start with the concept of *literacy* in the context of cultural literacy, technological literacy, and environmental literacy, which suggests not only an understanding of content knowledge of a subject, but the ability to use this knowledge in a productive way (DeWaters et al., 2007). Using definitions of scientific, technological, and environmental literacy as models, DeWaters et al. established the most common and accepted definition of energy literacy, which encompasses content knowledge, attitude and personal responsibility, and behavioral actions (2007). Furthermore, the authors establish the goal of energy literacy is to create a student who understands how energy is used in everyday life, how energy production and consumption impacts environment and society, the need for energy conservation and alternatives to fossil fuels, the impact of personal decisions on global energy use, and chooses to make choices based on their knowledge of energy resource development and consumption (2007). Dewaters et al.'s definition and understanding of energy literacy has been used throughout recent energy literacy literature, as explored later (Lee et al., 2015; Brewer et al., 2011).

Finally, the United States Department of Energy have created a definition of energy literacy through their *Energy Literacy Framework* campaign which closely aligns with the literature's definition of literacy. The Department of Energy defines energy literacy as understanding the nature and role of energy in nature and in our lives. In addition, an energy literate person can apply this knowledge of energy to solve problems, think about energy in terms of whole systems, knows where their energy comes from and how much they use, can assess the reliability of information about energy and can make informed decisions, can communicate about energy, and strives to learn more about energy throughout their lives (US Department of Energy, 2017).

In practice, energy literacy is much more complicated than establishing a definition and a set of goals for an energy literate student. DeWaters et al. assert that a key metric that the educational community must answer is what kind and how much knowledge makes that student "energy literate." (2007). Furthermore, there is a well-documented disconnect between cognitive knowledge of energy and the environment, and actually performing responsible energy behaviors in everyday life (Dewaters & Powers 2013; Taber & Taylor, 2009; McCaffrey & Buhr, 2008; Chess & Johnson, 2007). Smart energy behaviors can also be limited by socioeconomic and geographical constraints, which are variables that may not be accounted for in the classroom. As such, it is important to be able to measure energy literacy in students (DeWaters & Powers 2013). DeWaters & Powers thus established the *Instrument Development Framework* criteria for measuring energy literacy based on benchmarks within the cognitive (content knowledge), affective (attitude and personal responsibility), and behavioral (energy aware behaviors) attributes of energy literacy. These criteria, that were also used to assess energy literacy in Taiwan, are summarized in the table below by Lee et al. (2015) (Table 1).

Domain	General characteristics	Examples of benchmarks
Cognition	1. Knowledge of basic scientific facts	Definition/forms of energy
	2. Knowledge of issues related to energy sources and resources	Renewable and nonrenewable resources
	3. Awareness of the importance of energy use for individual and societal functioning	Society's need for energy
	4. Knowledge of general trends in US and global energy resource supply and use	Relative abundance of energy resources in the US/globally
	5. Understanding of the impact energy resource development and use can have on society	Societal impacts related to energy resource development
	6. Understanding of the impact energy resource development/use can have on the environment	Impact of developing energy on all spheres of the environment
	7. Knowledge of the impact individual and societal decisions related to energy resource development and use	Importance of energy saving and improved efficiency of energy use
	8. Congitive skills	Ability to examine one's own beliefs and values
Affect	1. Concern with respect to global energy issue	Values energy education
	2. Positive attitudes and values	Prevention of societal problems related to energy use
	3. Stron efficacy beliefs	Internal locus of control
Behavior	Predispositions to behave	
	1. Willingness to work toward energy saving	Considers energy impacts of everyday decisions
	2. Thoughtful, effective decision-making	Evaluates pros and cons related to energy consumption
	3. Change advocacy	Remains open to new ideas
	Behavior	
	1. Willingness to work toward energy saving	Exhibits energy saving habits at home and in school
	2. Change advocacy	Encourages others to make wise energy-related actions

Table 1: Example characteristics and benchmarks of DeWaters & Powers *Instrument Development Framework* (2013). Table from Lee et al. 2015.

Case Studies in Energy Literacy

Though DeWaters & Powers have provided a starting point for defining and measuring energy literacy in practice, there are a number of case studies in the literature that further establish what energy literacy entails. In 1989, Barrow & Morrisey report on energy literacy of ninth grade students in Maine after funding from the United States government was used to establish energy education programming and teacher training. The authors compared students who had successfully completed these energy literacy programs with counterparts in New Brunswick, Canada to measures the effectiveness of these government-funded programs. Energy literacy was assessed using the *Test of Energy Concepts and Values* questionnaires developed by Holden & Barrows in 1984. This test included 39 questions related to attitude about energy and 35 questions testing knowledge of energy concepts. The authors found that the energy literacy of students who had completed the energy curriculum in Maine had statistically higher energy literacy. The results also indicated that males had significantly higher energy literacy than females in both Maine and New Brunswick. However, in both areas the energy literacy of the students was low, suggesting that even though the students that had gone through the energy curriculum had higher literacy, the curriculum was insufficiently implemented to achieve satisfactorily literate students (Barrow & Morrisey, 1989).

In Greece, Zografakis et al. measured the efficacy of a special energy-themed project in increasing the energy knowledge of both students and their parents (2008). This project-based learning initiative included educational materials about environmental administration, the relationship between energy and the environment, renewable energy, and energy conservation. Materials included a toolkit for educators with materials to be used in class, as well as materials students could take home as reminders to save energy. At the end of the educational experience, students completed a survey, and then brought a survey home for parents or guardians to complete. The survey questions were first given at the beginning of the school year to create a baseline level of energy attitudes and then given again at the end of the school year to measure how the students' attitudes have changed after completing this energy project. The questions were all related to energy consumption and were asked both directly and indirectly. For example, when asking whether certain energy-saving behaviors were done in the home, a direct question would be about turning off lights and an indirect question would be about opening windows for fresh air. The results of the questionnaire showed that in 12 of the 13 energy saving behaviors, there was a statistically significant difference in students answers before and after the project. Similarly, there was statistically significant differences in 7 out of the 10 behaviors on the parents' questionnaire. These results suggest that both parents and students performed more energy saving behaviors after the completion of the program. The authors therefore argue that the energy literacy of the students increased, but that similar programs must be done each year to provide repetition to ensure that these energy saving behaviors continue for the long term (Zografakis et al., 2008).

A campus-wide energy competition that was established at the University of Hawaii provides another case study of energy literacy acquisition (Brewer et al., 2011). The energy competition, called the Kukui Cup, is a computer-based “game” designed for freshmen students living in the university dorms. The students interact with a software that provides different visualizations about energy use as well as workshops and excursions to teach them about their energy behaviors and how that impacts wide-scale energy production and consumption (Brewer et al., 2013). The participating students answer a pre-survey during the first week of the competition to establish a baseline value of energy knowledge. At the end of the competition, students complete another survey to gauge whether their energy literacy had changed. In addition to using the online software as a game in which students can learn about energy, the researchers also measure the amount of electricity each floor of the dorms used throughout the length of the competition so as to correlate gains in energy literacy with actual energy saving behaviors (Brewer et al., 2011). The researchers provide both consistent feedback about energy usage, as well as an energy usage goal to work towards that is based on a dynamic baseline of energy used. Upon analysis of these competitions, the authors highlight three important factors to successfully increase energy literacy; first that feedback should be in the form of actionable suggestions, that the feedback should be something the student can and will do even after the competition ends (termed “sticky” feedback), and that feedback must be coupled with energy content knowledge to help students understand why certain actions will reduce energy consumption (Brewer et al., 2013). A similar dorm energy competition at Oberlin College uncovered compatible results to the Kukui Cup in that students were able to reduce their energy and water usage in the dorms. The researchers at Oberlin suggest that to increase energy literacy that will lead to actual energy-saving behaviors, students must receive feedback about their energy use and small incentives or goals to help motivate them to reduce energy usage (Peterson et al., 2007).

As noted earlier, DeWaters et al. have conducted significant research about energy literacy. DeWaters & Powers have developed a survey to measure energy literacy, which they have used to assess energy literacy among middle and high school students in New York state. This survey uses a

Likert-type scale to assess energy literacy within three different subscales: cognitive, affective, and behavioral knowledge about energy. The questionnaire varies slightly between middle and high school students to account for different levels of schooling. The authors then recruited 38 high school and 41 middle school teachers, most of whom taught science and/or technology classes, throughout New York state. The students who took the survey were from a variety of ethnic backgrounds and were approximately equally split between males and females. Socioeconomic status also varied widely between students. It is important to note that over 90 percent of teachers that administered the survey reported that they had spent fewer than five classroom hours teaching about energy (DeWaters & Powers 2011). This indicates that the students taking the survey were relying only on what they already knew about energy without being specifically taught energy lessons in preparation for this survey.

Analysis of the survey results illustrate that in general the energy literacy of middle and high school-aged students in New York state was low. Though high school students scored significantly better on cognitive knowledge questions than middle schoolers, the scores for high school students were still below average. In particular, the concepts that students knew the least about include energy conservation, the relationship between power and energy, what energy resources exist, and home energy use. Interestingly, high school students scored significantly worse than their middle school counterparts on the behavioral section. Both groups of students scored better on the affective section relative to the other sections, with high schoolers scoring significantly higher than the middle school students. These affective scores indicate that high school students have more positive attitudes and values about energy. The authors conclude that since high school students scored better than middle school students in cognitive and affective categories, but lower in behavioral categories, between middle school and high school students learn more about energy and have more positive values towards the need for energy conservation, but that they engage in less energy saving behavior. This disconnect highlights the need for stronger educational programs on practical energy issues and current energy events. The authors conclude by noting that students report that most of their energy knowledge does come from school, again underscoring the importance of high-quality energy curriculum in improving energy literacy (DeWaters & Powers, 2011).

The energy literacy questionnaire developed by DeWaters & Powers and used in New York state as described above was slightly modified and used by Lee et al. to measure the effectiveness of an energy literacy program, *Nurturing Talent for Energy Technology* (NTET), established by the Taiwanese Ministry of Education as part of the Taiwan Bureau of Energy's energy policy (2015). The researchers administered the survey once to over 1200 9th grade students from across the country, and to over 1100 12th grade students who had been a part of the NTET program for 2 years. In both student groups, the proportion of male to female students was approximately equal, and most students reported that they learned about energy mostly from school programs. Unlike the results found in New York state, energy literacy in Taiwan was higher in both groups of students. Both 9th and 12th graders performed well on energy concept knowledge with a few exceptions, such as different types of alternative energy sources. The students also scored similarly in the affective and behavioral domain, with higher scores in the affective, suggesting that the students understand the importance of energy, but do not necessarily participate in energy saving behaviors (Lee et al., 2015). This disconnect between the behavioral domain and the cognitive and affective domains was also seen in DeWaters & Powers results in New York state (DeWaters & Powers, 2011). Lee et al.'s work shows that in Taiwan, energy literacy seems to be at a higher level, perhaps because of the NTET curriculum that the 12th grade students had taken (2015). However, energy literacy in 9th grade students was also high, which the authors attribute to energy being a highly publicized issue both in schools and in Taiwanese public consciousness. Within the behavioral domain, students seemed to have less of a connection between energy and their own personal behaviors, indicating a need for more educational emphasis on the relationship between energy and a student's life (Lee et al., 2015). Similar to DeWaters & Powers conclusions, the results of this study suggest that future energy programs and curriculum continue to emphasize energy knowledge as well as values, attitudes, beliefs, and judgements (Lee et al., 2015; DeWaters & Powers, 2011).

The most evident and troubling theme that emerges from this cross section of energy literacy research is that in general, energy literacy among students in the United States is low. However, it is encouraging to see that the existence of energy education curriculum in schools does seem to increase energy knowledge (Lee et al., 2015; Zografakis et al., 2008; Barrow & Morrisey, 1989) and that students self-report as having learned most of what they know about energy from school (Lee et al., 2015; DeWaters & Powers, 2011). This theme suggests that a strong energy curriculum is essential to improve energy literacy. Furthermore, as suggested in Lee et al. (2015), DeWaters & Powers (2011), and Brewer et al. (2013), though energy content knowledge is important, a successful curriculum must also include information about beliefs, values, and how energy is related to students' lives. There is a disconnect between the cognitive and behavioral domains, which means that the content knowledge must be coupled and in line with feedback and information about how to make long-lasting behavioral changes (Brewer et al., 2013; Dewaters & Powers 2013; McCaffrey & Buhr, 2008; Chess & Johnson, 2007). Finally, as cited in Zografakis et al. (2008) and echoed in Lee et al. (2015), it is important to provide energy lessons each year of school to both underscore its importance and to ensure long-term behavioral changes. This concept of "sticky" behaviors that students can implement throughout their lives, even after leaving school, was also recommended by Brewer et al. (2013). Given these emerging themes, it is clear that in addition to sound content knowledge about energy issues, it is essential for any energy curriculum to address the relationship between the student and to current energy issues at various scales.

Misconceptions about Energy

In addition to low energy literacy of American students, current research suggests that the American public holds a number of misconceptions about energy use, conservation, and efficiency; as well as alternative or "green" energy sources (Dorji et al., 2015; Attari et al., 2010; Dietz et al., 2009; Gardner & Stern, 2008). These misconceptions are often strongly rooted and difficult to change (Taber & Taylor, 2009). However, these misconceptions provide a starting point from which educators can connect classroom content to the students' lives, and then correct these misconceptions. The literature suggests that students hold misconceptions and lack content knowledge about energy in a variety of different categories, but two of the most commonly misunderstood categories are the difference between energy conservation versus energy efficiency and which behaviors save the most energy; and being able to define exactly where energy comes from and what "alternative" energy is (Celikler & Aksan, 2015; Bodzin, 2012; Zyadin et al., 2012; Attari et al., 2010; Gardner & Stern, 2008). These two categories of energy misconceptions are explored in greater detail below.

Energy Use, Conservation, and Efficiency

As mentioned to earlier, though a reduction in personal energy use could provide steep reductions in greenhouse gas emissions, many are still unaware of how much impact their own behaviors can have on global carbon dioxide emissions (Dorji et al., 2015; Dietz et al., 2009; Gardner & Stern, 2008). A survey of over 500 participants revealed that people tend to underestimate how much energy is used and underestimate how much energy could be saved by doing certain behaviors. Furthermore, people tend to be unaware of the relative energy used by certain devices and actions, which could help people make more informed choices (Attari et al., 2010). Research has also shown that the American public is far more familiar with, and tend to focus more heavily upon, energy conservation (physically using less energy), rather than energy efficiency (using less energy to complete the same task). However, energy efficiency actions generally lead to more energy saved and greater curtailment of carbon dioxide emissions (Attari et al., 2010; Gardner & Stern, 2008). Therefore, it is essential to disentangle energy conservation and energy efficiency, and effectively communicate which behaviors lead to the greatest energy savings. To do this, it is necessary to create curriculum that helps students learn about household energy consumption, conservation, and efficiency (Dorji et al., 2015).

One of the most important misconceptions students have about energy usage is simply which devices and actions in their lives use the most energy. Taber & Taylor (2009) administered surveys and conducted a series of interviews to learn more about misconceptions primary school students had about climate change and energy use. Overwhelmingly, students cited lighting as the largest user of electricity, simply because lights are so visible to students. Even after curricular interventions, the students still thought lighting was a major electricity factor, as well as TV's and refrigerators, rather than the actual main electricity consumers: heating and cooling systems. The authors indicate that these heating and cooling systems are harder to "see" as energy users, and are thus often overlooked by the students surveyed (Taber & Taylor, 2009). This misconception about how much energy is used for heating and cooling was also found in a study of urban eighth graders' knowledge of energy in the US state of Pennsylvania. In this study, less than 25 percent of students in the study correctly identified heating and cooling as the largest source of electricity consumption (Bodzin, 2012).

Misconceptions about energy efficiency versus energy conservation are also important to address because these concepts are often conflated by the general public (Attari et al., 2010; Gardner & Stern, 2008). These misconceptions can then be passed on to students because much of their experience of household energy and conservation comes from their family background (Taber & Taylor, 2009). As Gardner & Stern (2008) point out, energy conservation and efficiency has become a popular topic to write and report about, citing articles from *Time* magazine and handbooks distributed by environmental groups. However, the exact amount of energy saved is rarely addressed or measured in these information pieces. Therefore, it is difficult for people to know which actions to undertake to save the most energy (Gardner & Stern, 2008). Furthermore, when asked to generate a list of energy saving behaviors, people most often list energy conservation behaviors rather than energy efficiency improvements. Indeed, when asked about the "most effective thing" for saving energy, just under 12 percent of survey respondents answered with an energy efficiency behavior (Attari et al., 2010). The fact that conservation is more readily thought of than efficiency is troubling because, as mentioned above, Gardner & Stern report that energy efficiency actions are often more effective that energy conservation. For example, the authors cite buying a fuel-efficient car, and energy efficiency activity, will reduce carbon dioxide emissions far more than carpooling to work, lowering highway driving speeds, and consolidating errands into fewer trips; all of which are energy conservation activities. In addition, efficiency actions are often one-time or few-time actions such as buying a more efficient appliance or adding household insulation; whereas energy curtailment involves repeated actions over a long period of time, which may be hard to continue over time (Gardner & Stern, 2008). These important concepts are important to teach in school energy curriculums because the relative magnitude of energy saving behaviors is rarely obvious. Furthermore, as Taber & Taylor suggest, empowering students with real-time information about how to effectively save energy can help them make changes in their households (2009).

One of the most difficult misconceptions about energy efficiency versus conservation is the cost of each different action. Energy efficiency measures often require a high upfront cost, whereas conservation is often cost-free. However, over the lifetime of an efficient appliance, device, or lightbulb, energy users often save money by using less electricity and therefore paying less on an electric bill. For example, though efficient lightbulbs such as CFL's or LED's are more expensive than traditional incandescent bulbs, over the course of the lightbulb's lifetime, the CFL or LED bulb will save people significant amounts of money in electricity purchased versus the conservation action of turning off a light when leaving a room (Gardner & Stern 2008). Indeed, popular conservation actions such as turning off a light saves relatively little energy at all (Attari et al., 2010; Gardner & Stern 2008). This idea of cost over a lifetime, coupled with lifecycle analysis of the energy used to produce certain goods, are powerful misconceptions that offer an opportunity for teaching students about energy usage, as well as helping students improve their numeracy. Though being numerically literate is valuable in its own right, Attari et al. found that more numerically literate people tend to be better able to assess the relative energy use of different behaviors and appliances (2010). By helping students to correct these misconceptions of energy consumption and savings, the next generation of energy users may be better able to make smarter energy decisions.

Traditional and Alternative Energy Sources

Misconceptions about energy sources, including fossil fuels and alternative energy generation are also apparent in the literature. Bodzin reports that students in his study of eighth graders in Pennsylvania hold several misunderstandings about the advantages and environmental impacts of various electricity-generating sources. For example, only 13 percent of students knew how petroleum was formed, and only 20 percent knew how coal was formed. Furthermore, over 50 percent of students though nuclear power was nonrenewable because it created radioactive waste, which calls into question whether students truly understand the concept of renewable versus nonrenewable energy (2012). In another study done in Turkey, 89 percent of students could correctly identify solar power and 86 percent could correctly identify wind power as renewable energy sources, but only around half identified geothermal, biomass, wave power, and hydrogen as renewable. Furthermore, 21 percent thought that nuclear power was renewable (Celikler & Aksan, 2015). These misconceptions about what is renewable and what is nonrenewable illustrate that while students may have a broad understanding of more commercially available technologies, they lack more detailed understanding of less common energy forms. American students also hold misconceptions about the energy mix in the United States, with over 73 percent of students not knowing that most of the electricity in this country comes from burning coal, and almost 80 percent were unsure of what the most consumed energy source was (petroleum, mostly used in the transportation sector) (Bodzin, 2012).

Students also hold some misconceptions about alternative or “green” energy sources. As seen above, students do seem to understand what wind and solar power are, but have less familiarity with other renewable energy sources such as geothermal and biofuels (Celikler & Aksan, 2015; Bodzin, 2012; Zyadin et al., 2012). In a study of students’ knowledge of renewable energy in Jordan, the authors concluded that students misunderstand the fundamentals of these lesser-known renewable energy technologies because they have a less developed market than wind and solar and thus are under-emphasized in renewable energy curricula. Despite these misconceptions though, students were overwhelmingly in favor of renewable energy utilization (Zyadin et al., 2012). Coupled with a better renewable energy curriculum, these positive attitudes towards renewable energy may present an opportunity for further renewable energy uptake in Jordan. Similarly, in a renewable energy awareness study done it Turkey, it was evident that students held many misconceptions about the actual mechanisms by which renewable energy technologies such as solar panels, hydroelectric dams, and biogas create usable energy. Another important misconception uncovered in this study was that many students thought that renewable energy technologies do not have any negative environmental consequences (Tortop, 2012). This is an important misconception to address because all energy resources have environmental impacts which must be weighed against the benefits of each source.

Gossling et al. (2005) also highlight student misconceptions about the distribution and market dynamics of renewable energy sources. For example, in their study, many students expressed concern about how a country would get energy during periods of calm when wind turbines do not generate electricity. Students did not know about the concept of a suite of energy-producing technologies that work in concert to meet real-time energy demand. Furthermore, students cited renewable energy as "too expensive," but do not know how much these sources actually cost compared to traditional fuels. Along those lines, students did not know about energy costs for consumers, and what an energy bill would look like with renewable energy generation in the electricity mix (Gossling et al., 2005). This study reveals that an energy curriculum should address both the technological aspects of renewable energy, as well as the fundamental concepts of energy mixes and how electricity is delivered to electricity consumers.

Conclusion

This literature review seeks to evaluate current research about students' knowledge and misconceptions of energy. By examining studies about energy literacy, emerging themes suggest that in general, energy literacy among students in the United States is low and that there is a need for quality energy curriculums. In addition, a successful energy curriculum will have components that address the cognitive, affective, and behavioral domains to ensure that students can reconcile the concepts that they learn with their own values and behaviors. This is essential for students to be able to form smart energy behaviors and habits for the rest of their lives. Furthermore, students hold a number of misconceptions about energy, particularly about energy conservation versus efficiency, and the mechanisms of renewable energy generation and use. These misconceptions must be corrected in order for students to be able to make informed energy decisions in their own lives. In the following energy-themed curriculum unit, these lessons from the literature will be applied so as to establish a quality set of activities that will help to foster higher energy literacy in high school students.

Promoting Energy Literacy through Teaching Students about Energy Use and Behavior

A Systems Thinking Curricular Guide of Best Energy Activities for Teaching Energy Use and Behaviors

Curriculum Guide Compiled and Evaluated by Katie Halpin

Authors of curricular activities cited within individual activities

Outline of Activities:

Unit 1: Addressing Misconceptions and Energy Behaviors

- Engage students in a brainstorming activity to elicit definitions and examples of behaviors that demonstrate energy efficiency versus energy conservation.
- Empower students to conduct a classroom or a school-wide energy audit to see where energy is being used and where energy efficiency or conservation can be employed. After the guided classroom energy audit, students can perform a personal energy audit in their homes.
- Students will be challenged to think about the scale at which different behaviors will save different amounts of energy. This includes scaling up individual energy saving behaviors to think about how much energy the whole class, the whole school, or the whole country could save through various changes.
- After learning about various energy conservation and efficiency behaviors, students will come up with their own DIY energy saving challenge – they will have to design and implement a way to save more energy in their lives. They will also calculate how much energy they will save with this behavior or project.
- Final project: students will develop an argument about what they think would be the most effective energy saving behavior that the whole school could adopt in order to save energy. The students will support their claim with evidence and reasoning that they will then present to school administrators or employees.

Unit 2: Energy & Me: Where Does My Energy Come From?

- Students will learn about one energy generation source in detail and then teach each other about these sources in a jigsaw-format so that all students get an overview of each energy source. They will then engage in a game to weigh the advantages and disadvantages of the different energy sources.
- Students will explore ways to generate a consistent current of electricity by creating a wind turbine using tools from a Maker's Space or using classroom craft supplies.
- Case study: Field trip to an Indiana wind farm. The class will investigate a wind farm in Indiana, and if possible, take a field trip to the farm itself. Students will learn about renewable energy options in Indiana and contrast those options with the traditional fuel source (coal). Students will also learn about the various challenges of renewable energy.
- Introduction to how energy is delivered to residential customers, and what an energy bill looks like. Students will explore an electricity bill, and whether they can "opt in" to purchasing green energy from the utility company. Students will also interact with energy data to determine what an energy demand curve looks like, and what implications energy demand dynamics has on the feasibility of renewables (ex. Solar "duck" curve).
- Final project: would you install a solar panel on your roof? Students will conduct research to determine if they think installing a solar panel on the roof of their home would be a viable investment. Students will make a claim and then support their claim with evidence and reasoning that must address environmental, sociopolitical, and economic factors.

Indiana State Standards Alignment (for high school environmental science):

SEPS.1 Posing questions (for science) and defining problems (for engineering).

SEPS.2 Developing and using models and tools.

SEPS.3 Constructing and performing investigations.

SEPS.4 Analyzing and interpreting data.

SEPS.5 Using mathematics and computational thinking.

SEPS.6 Constructing explanations (for science) and designing solutions (for engineering).

SEPS.7 Engaging in argument from evidence.

SEPS.8 Obtaining, evaluating, and communicating information.

11-12.LST.1.1: Read and comprehend science and technical texts within a range of complexity appropriate for grades 11-CCR independently and proficiently by the end of grade 12.

11-12.LST.3.1: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

11-12.LST.4.1: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

11-12.LST.4.3: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

11-12.LST.5.1: Write arguments focused on discipline-specific content.

11-12.LST.7.1: Conduct short as well as more sustained research assignments and tasks to answer a question (including a self-generated question), test a hypothesis, or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

11-12.LST.7.2: Gather relevant information from multiple types of authoritative sources, using advanced searches effectively; annotate sources; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; synthesize and integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation (e.g., APA or CSE).

Env.2.4 Recognize and describe the different sources of energy, including fossil fuels, nuclear, and alternative sources of energy provided by water, wind, geothermal, biomass/biofuels, and the sun.

Env.2.5 Give examples of the various forms and uses of fossil fuels and nuclear energy in our society.

Env.2.6 Understand and describe how layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Recognize that by burning these fossil fuels, people are passing stored energy back into the environment as heat and releasing large amounts of matter such as carbon dioxide and other air pollutants.

Env.2.7 Differentiate between renewable and nonrenewable resources, and compare and contrast the pros and cons of using nonrenewable resources.

Env.2.8 Cite examples of how all fuels, renewable and nonrenewable, have advantages and disadvantages that society must question when considering the trade-offs among them, such as how energy use contributes to the rising standard of living in the industrially developing nations. However, explain that this energy use also leads to more rapid depletion of Earth's energy resources and to environmental risks associated with the use of fossil and nuclear fuels.

Env.2.9 Describe how decisions to slow the depletion of energy sources through efficient technologies can be made at many levels, from personal to national, and these technologies involve trade-offs of economic costs and social values.

NGSS Standards Alignment:

HS-PS3-1 Energy: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-3 Energy: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-2 Earth & Human Activity: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4 Human Sustainability: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

***Note: These activities should be done after students have learned about global climate change. Students should be aware of how energy use burns fossil fuels that emit carbon dioxide to the atmosphere, which contributes to climate change, and thus why we must examine our energy use and find ways to decrease it. Students should also be aware that most electricity in the United States comes from fossil fuels, and that we must find alternative ways to generate electricity in an effort to decarbonize society.**

Unit 1, Activity 1: Energy Efficiency versus Energy Conservation

Introduction to Conservation & Efficiency in Personal Energy Use
Lesson by Katie Halpin

Objectives:

1. Students will be able to define energy conservation and energy efficiency
2. Students will be able to identify if an action is an energy efficiency action or an energy conservation action
3. Students will be able to verbalize the connection between climate change and personal energy use
4. Students will be able to give an example of why someone may resist incorporating energy saving behaviors into their lives

Materials:

1. Large whiteboard
2. At least 2 whiteboard markers

Introduction – Identifying Actions:

1. Break students into 2 teams. Each team will choose a representative to go to the board to write.
2. The teams will have 1 minute to tell the representative at the board any behaviors that they currently do or can do to reduce the amount of energy they personally use (i.e. recycling does not reduce personal energy consumption – think about what will lower your electricity bill). The representative will write down as many things as possible to generate a list of energy-saving behaviors.
3. At the end of the 1 minute, allow the teams to briefly compare lists to determine if they have overlooked any energy-saving actions.

Activity – Defining Conservation & Efficiency:

1. Now tell the students that we generally separate energy-saving behaviors into 2 categories: conservation and efficiency.
2. Ask the students if they can define conservation vs. efficiency. Come up with a clear definition for each.
   a. *Conservation*: Any behavior that results in the use of less energy (doing the same behaviors, but less of the behavior – driving less, turning off lights, etc.) *
   b. *Efficiency*: Any behavior that requires less energy to perform the same function, often via switching technologies (replacing lightbulbs with LEDs, buying more fuel-efficient car) *
3. Now have the students look back at their lists and in their teams have them verbally categorize each activity as a conservation action or an efficiency improvement. Allow students to try and categorize as many actions as possible.

*Definitions for *conservation* and *efficiency* derived from EIA website, https://www.eia.gov/energyexplained/index.php?page= about_energy_efficiency and Shahzeen Attari, School of Public & Environmental Affairs, Indiana University

4. Wrap up the activity by going over the student categorizations:
    a. Point to several items on the different lists and ask them if it is conservation or efficiency to assess their categorizations.
    b. Ask them if there were any actions that they could not categorize and discuss why they are either conservation actions or efficiency actions

Discussion - Connection to Climate Change:

1. Next, have the students think about energy conservation versus energy efficiency and write what they think are the relative benefits of each. Which behaviors do they think save the most energy?
2. Then, have them connect the idea of implementing energy curtailment behaviors to global climate change – why is it important to reduce energy use in our daily lives (what is the relationship between energy use and climate change)? What are the implications of energy use?
3. Once the students have written something down, have them discuss with a partner or a cooperative learning group. Then, have the groups share out what they talked about with the rest of the class. Be sure to highlight that *energy efficiency behaviors typically save more energy than energy conservation* (Gardner & Stern, 2008). Ask them why might we see an emphasis on conservation actions over efficiency actions? Is this problematic given the reality of global climate change?
4. The last question should lead into some of the social implications of various energy behaviors (efficiency upgrades can be expensive). What are some of the other barriers and issues? Can all people implement various energy efficient and energy conservation measures? Why might someone resist or choose not to implement a certain behavior?
5. Have students think about their attitudes towards saving energy. Do students think this is an important thing to do? Have the students encountered someone that does not care about saving energy? Why might a person feel this way? How can we talk to people, particularly those who do not care about saving energy, about climate change and changing our behavior to save more energy?
6. Depending on the level of students, you can give them Gardner & Stern's paper on personal energy behaviors (citation below). This is an excellent article addressing many of the issues surrounding personal energy use, but may be a cognitive challenge for some students. This paper can be given either before (which will make it easier for them to do the activity above, but will tell you less about their prior knowledge about personal energy behaviors) or after this lesson (preferred).

Gardner, G. T., & Stern, P. C. (2008). The short list: The most effective actions US households can take to curb climate change. *Environment: science and policy for sustainable development*, 50(5), 12-25.

Wrap-Up and Assessment:

- Have students give definitions of conservation and efficiency in their own words.
- Use questioning to test whether they can categorize different energy behaviors as conservation or efficiency (you can use behaviors from their lists or come up with new behaviors)
- Have the students write on an exit slip:
    - what is the connection between energy saving behaviors and climate change?
    - what is one reason why someone may resist saving energy, and what could you say to them to encourage them to save energy?

Unit 1, Activity 2: Classroom Energy Audit

Conducting an Energy Audit to Identify Energy Waste

Lesson is a compilation of energy audits designed by US EPA, Audubon Naturalist Society, and Minnesota Energy Challenge. Homework comes from Clarkson University Energy Systems Curriculum.

Objectives:

1. Students will be able to answer questions about energy use in the classroom
2. Students will be able to calculate energy use from lighting in the classroom
3. Students will be able to use various pieces of equipment to measure information about energy
4. Students will be able to evaluate energy use in the classroom and where energy is being wasted

Materials:

1. Student Worksheets
2. Thermometer
3. Watt Meter (if available)
4. Paper clips
5. Strips of light paper such as tissue paper

Introduction – Energy Use in the Classroom:

- Start by asking students to define energy conservation and energy efficiency in their own words. Have other students give examples of each type of behavior
- Next, ask students where they think energy is used in the school building/classroom (make a list of "energy users" on the board). Which of these "energy users" uses the most energy?
- Ask where energy could be wasted in the classroom. What do we mean by "wasted energy"?
- Today students will be conducting an energy audit to qualitatively see where energy is being used in the classroom, and if any energy is being wasted. Break students up into groups of 2-4 for this activity.
- Prior to giving students the worksheet and allowing them to conduct their energy audit, have students make a "draft tester" by attaching a small paper clip to the end of a strip of tissue paper (see image, right). At least each group should have a draft tester, but if you would like each student can make a draft tester.

Image from US EPA energy audit

Activity – Classroom Energy Audit:

- Distribute Student worksheets (following). Have each group go through the worksheet to qualitatively measure energy use (and energy waste) in the classroom.

Student Worksheet: Classroom Energy Audit
(combination of energy audits from by US EPA, Audubon Naturalist Society, and Minnesota Energy Challenge)

Directions: Answer the following questions about classroom features that contribute to energy use. If you don't know an answer, seek help from a peer first and then your instructor.

1. Where is the thermostat located?

    a. It should be located on inside walls, away from a bright light source (such as sunlight) or a heating or air conditioning vent. Is it? Yes No

2. What setting is the thermostat reading? _______________

    a. It should be set at 68 degrees Fahrenheit in winter or 78 degrees Fahrenheit in summer. Is it? Yes No

3. Do you have windows in your classroom? Answer these questions, if you have windows.

    a. How many windows does your classroom have? ________________

    b. How many layers of glass does each window have? 1 2

    c. Does your classroom have window coverings that allow you to block out intense sunlight during hot days? Yes No

    d. Which direction are the windows facing? N S E W
    (The sun rises in the east and sets in the west. We get the most sunlight from the south and have the most shade on the north side of homes, buildings and trees)

    e. Take the small piece of paper and paper clip you made. This is a "draft detector." Walk up to the window and hold the piece of paper at four different spots along the edge of the window, where the window meets the wall. Hold it still for about 15 - 30 seconds in each spot. Be sure to get really close to the window, if you can do it safely, and make sure that the heating vents aren't blowing the paper.

    Does the paper move? Can you feel warm or cold air coming in through the window? If you can feel air move, the windows are not energy-efficient. Are your windows energy-efficient? Yes No

4. Now take your draft detector to your classroom door. (If you have a door to a hallway and a door to the outside, do this activity with both doors.)

    a. Place the detector along the sides of the inside of the door, where it meets the walls, and along the floor. Do you detect any air moving through the cracks between the door and the wall or the floor? If you can feel any air moving, your door is not energy-efficient. Is your door energy-efficient? Yes No

    b. Place the detector along the sides of the outside of the door, where it meets the walls, and along the floor. Do you detect any air moving through the cracks between the door and the wall or the floor? If you can feel any air moving, your door is not energy-efficient. Is your door energy-efficient? Yes No

5. Does your classroom have a floor covering, such as carpeting? Yes No

6. How high is your ceiling? (Use caution when trying to determine this.) Is it 8 feet or less? Yes No

7. If you can safely open the air conditioning or heating unit in the classroom, do so, and look at the filters. Are they clean (little dust or dirt, not clogged)? Yes No

8. Are the lightbulbs used in your classroom energy-saving bulbs? (You might need to ask your facilities manager this question.) Yes No

9. Are all the desks and chairs away from heating or cooling vents? Yes No

10. Now we will look at some of your personal activities in your classroom that affect energy use.

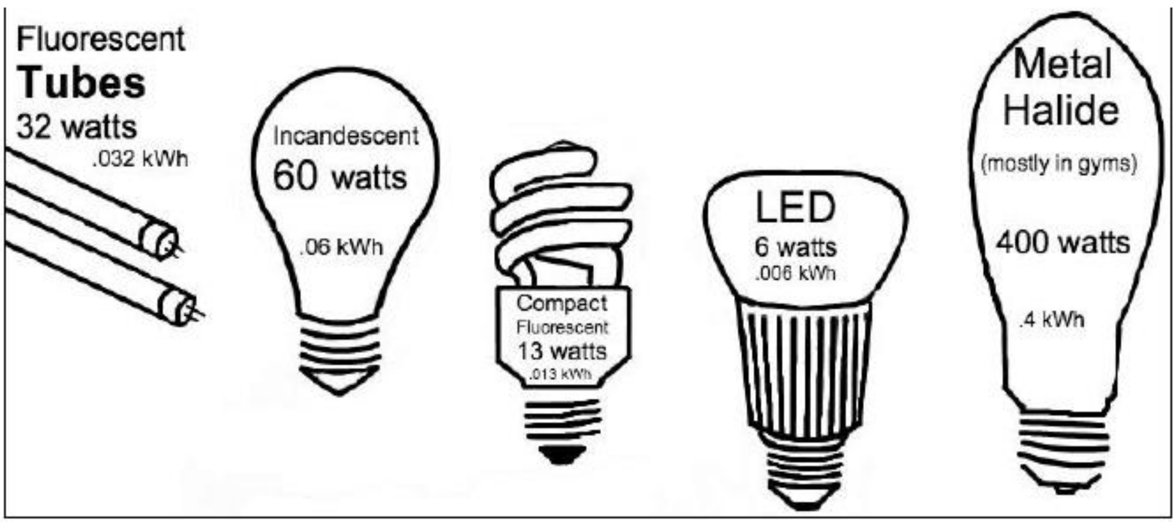
    a. Do you turn off the lights if you are the last one out of the room? Yes No

    b. Do you avoid putting your textbooks, notebooks, etc. on top of heating or cooling vents? Yes No

Directions: For the following charts, fill in the correct information using the tools provided to you by your instructor.

LIGHTING

How many lightbulbs or light tubes do you find?	**A**
How many hours are the lights ON each day? (you may need to estimate)	**B**
Find the type of light pictured below and enter the amount of energy it uses (watts) here	**C**
Find the total energy used by the lights using this equation: **A x B x C =**	**Total energy used for lighting (Watts/hour)** **A x B x C =**



WATT METER

Electrical Device	**Hypothesis (Circle Your Prediction)**	**Actual Watt Meter Reading**
Laptop	0 5 25 50 75 100 watts	
Cell phone charger	0 5 25 50 75 100 watts	
Pencil sharpener	0 5 25 50 75 100 watts	
Other classroom device: ____________________	0 5 25 50 75 100 watts	

THERMOMETER

Location	**Prediction °F**	**Actual Temperature**	**Within ideal range of 68°-78°F?**
On a desk in center of the room			
Near the windows			
Near the thermostat or heat/air unit			

Energy Audit Analyzing Questions:

Directions: Answer the following questions based on your energy audit.

1. If you answered "no" to any of the questions at the beginning of the energy audit, that means that the classroom is not using energy efficiently. By improving upon these things, the classroom will use less energy, thus contribute less to global climate change. Where in the classroom did you see wasted energy (which questions did you answer "no" to)?

2. After calculating how much energy is used in lighting the classroom, do you think this is a lot of energy? Why or why not? Could we cut down on this energy use at all?

3. How did your predictions of the amount of energy various electronics use compare to their actual energy usage? Are you surprised by these differences? Which item used the most energy? Which item used the least?

4. Did the temperature change in different parts of the room? If it did, what could this tell us about the energy we use to heat and cool our classroom?

Teacher Information about Energy Audit:

(from EPA “Simple Energy Audit”)

If you answered “yes” to most of the questions at the beginning of the energy audit, your classroom is doing well. But if you said “no” to three or more, you need to work with your teacher, facilities manager, or other adult to improve these areas.

Here’s why your answers matter:

1. If your thermostat is located too close to a strong light or heat source, it will not properly measure the room temperature, which means that energy will be wasted because the heater or air conditioner runs more than it needs to. It also could mean that you are uncomfortable in your classroom, because if the thermostat is near a source of heat or air-conditioning, it will turn off well before the entire room is heated or cooled.

2. If your thermostat is set too high in winter or too low in summer, you are wasting energy. Ask the person responsible for energy management in your school to check your thermostats and make sure that they are working properly.

3. If your windows do not have the ability to block out intense sun, your air-conditioning costs are too high, or your comfort level is lowered (because the room cannot cool down). If you see or feel air moving through the edge of the window, this means you are losing energy from your classroom, and the windows need to be caulked, sealed, or covered by a storm window system.

4. Your draft detector has helped you to determine whether your door is energy-efficient.

5. Carpeting helps keep rooms more comfortable and conserves heat.

6. Ceilings higher than 8 feet waste energy, because warm air moves to the top of the room instead of remaining near the floor where we are.

7. Clean filters conserve energy by allowing the unit to run efficiently. Dirty filters waste energy.

8. Energy-saving bulbs are more expensive to buy but save lots of money on electricity in the long term.

9. If furniture blocks heating or cooling vents, the furnace or air conditioner will insufficiently heat or cool the room.

10. When you wear clothes that are appropriate for the weather, you require less energy to keep warm or cool. Keeping lights on when you do not need them wastes energy. Again, if objects block heating or cooling vents, the furnace or air conditioner will insufficiently heat or cool the room.

Discussion – Making Sense of Energy Audit:

- After each group has completed their energy audit worksheets, bring the class together for a discussion to address the following:
    1. If appropriate, go over "energy audit analyzing questions". Alternatively, these questions could be collected and assessed as a formative assessment.
    2. Did the energy audit address most of the "energy users" that we identified at the beginning of class? Were there any "energy users" we did not think of at the beginning of class?
    3. What seemed to be using a lot of energy? Lights? Heat? Electronics?
    4. Where in the classroom could we implement either energy efficiency or energy conservation?
    5. Have the students answer the following critical thinking question either in their notebook, at the end of their energy audit, or in an online discussion post. If you choose, students can discuss their answers after writing them. This question will be a bridge to the next activity in which students will consider the scale of energy use.

       Critical Thinking Question: In your notebook, write down an example of "wasted energy" in your classroom. In the grand scheme of energy use worldwide, does this wasted energy matter (does it make a significant contribution to global climate change)? Now assume that every classroom in every school around the world also wastes energy in this way. Does this wasted energy matter? Explain why or why not.

Wrap-Up and Assessment:

- Why is it important that we conduct energy audits? Why do we want to know how much energy we are using/wasting?
- Where is energy being used in the classroom? What do students think uses the most energy? *(Teaching note: heating and cooling typically uses the most energy)*
- Where is energy being wasted in the classroom?
- For homework, students will complete an at-home energy audit exercise (following). This audit will have students track energy usage in their home over the course of a week. These data can be used in the following activity about energy calculations and scale of energy use.
- *Optional:* If time allows, students can fill out an exit slip as additional formative assessment. Exit slip questions could include: How can the classroom use energy better? What is still confusing about energy use after completing the energy audit?

Student Homework: At-Home Energy Audit
(Worksheet comes from Clarkson University Energy Systems Curriculum)

Directions: Find at least 5 items in your home that use electricity (preferably things that you personally use). Then, track how much time each electronic is used each day for 1 week. Record answers in the spreadsheet, below.

	Energy Tracker (Hours/Day)							Cost C	
Appliance	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total Hours	Wattage
EXAMPLES:									
Television (19")	1.50	2.50	2.00	1.00	2.50	2.50	3.00	15.00	100.00
Space heater	4.00	3.50	5.00	6.00	5.50	4.50	5.00	33.50	1500.00
Personal computer	2.00	1.00	1.50	0.00	1.00	2.00	2.50	10.00	200.00
YOUR APPLIANCES:									
								0.00	
								0.00	
								0.00	
								0.00	

***Note: Wattage of various appliances can either be found online (estimate) or on the device itself (on the informational tag on the device's cord). Use caution when looking for wattage information on the device itself.**

Discussion Questions:

Directions: Answer the following questions after completing your at home energy audit.

1. What three appliances consume the most electrical energy at your house?

2. Does an appliance or device that has a high wattage always use the most energy over the week or month? Explain.

3. What do you think you could do to reduce the amount of energy used in your house?

4. Electrical Energy is one of the critical energy resources in our daily lives. Describe how you might replace the work of three of the appliances / devices if you did not have electricity.

5. How do you think your house compares to average energy use in the state of Indiana? How does it compare to the rest of the country? How does it compare to the rest of the world?

Unit 1, Activity 3: Calculating Energy Use and Savings

Unit Analysis to Calculate Energy Use and Savings
Lesson by Katie Halpin, Clarkson University Energy Systems Curriculum, and The Need Project.

Objectives:

1. Students will be able to calculate the amount of energy something uses given wattage and time used
2. Students will be able to calculate how much it costs and how much carbon dioxide is emitted in using an appliance
3. Students will be able to communicate about the scale of personal energy use versus energy use by the entire school, community, and country

Materials:

1. At least a 4-function calculator for each student
2. Student worksheets

Introduction – Connecting our Energy Audit with Large-Scale Energy Use:

- Think back to your critical thinking question from the end of your classroom energy audit. Discuss your answer with the person sitting next to you/in a small collaborative learning group. Then, share answers out to the rest of the class.
- In the last activity we qualitatively assessed energy use in the classroom. Now we will quantitatively measure energy use. How might we calculate energy use? How could we use math to "scale up" our energy use to assess statewide, countrywide, or global energy use? (use these questions to elicit prior knowledge and general numerical literacy from students. This may guide how fast/slow this activity takes)

Preparing for Activity – Energy Units and Calculation:

1. Start with an introduction to energy units. Ask students how we measure energy? What units do we use?
2. Introduce relationship between power and energy
   Power = Energy/Time
   Energy = Power*Time

   Common **energy** units: Joules, Watt-hour, BTUs, etc.
   Common **power** units: Watts (J/s), Kilowatts, etc.

   For household energy measurements, we generally use kilowatt hours (kWh)
   1 kWh = 1000 Wh
   1 Wh = 3600 J

3. Have students list what appliances they have used so far today (ex. Laptop, hair dryer, toaster, coffee maker, etc. Then, have them look up online how much power (in Watts or kilowatts) each of these devices use (Michael Bluejay is a good resource for this).
4. Next, have students calculate the energy used by these appliances by multiplying the power times length of time using each appliance.

   Example: I blow dried my hair for 7 minutes this morning with a 1875 W blow dryer. How many Wh of electricity did I use?
   7 minutes = 0.12 hours; 1875 W
   1875 W * 0.12 h = 219 Wh
   (*Note, you can also have students convert between SI units to remind them of Joules)

   If various devices have "standby" power such as microwaves, tv's, cable boxes, etc. the students can also calculate total energy used (energy used during use and while on standby)

   Example: Assume you watch 1.5 hours of tv, followed by 3 hours of rest, followed by 1.5 more hours. How much electricity does your cable box use in a 24 hour day?
   Power while in use: 75 W
   Power while on standby: 30 W
   Time in use = 3 hours
   Time in standby = 24 – 3 = 21 hours
   Energy = Power * Time
   (in use power * time) + (standby power * time)
   (75W * 3hr) + (30W * 21hr) =
   =225 Wh + 630 Wh = 855 wh = 0.855 kWh

Activity – Calculating the Cost and Impact of Electricity Use:

- See handout "Cost of Using Electrical Devices" (following) for more practice with calculating energy use, cost of electricity, and amount of carbon dioxide produced per appliance.
  **Note: The students can either choose new electronics around the classroom, or use those appliances they tested with the Watt Meter in their energy audit (laptop, cell phone charger, pencil sharpener, another device)*

Challenge Questions:

1. Calculate the number of pounds (lbs) of carbon dioxide emitted from a car going 60 mph for 60 minutes (assumptions: 1 gallon of gas = 8887 g CO_2, 1 gallon of gas = 20 miles).
   Answer:
   60 miles*1 gallon/20 miles = 3 gallons gas used
   3 gallons gas * 8887 g CO_2/1 gallon = 26661 g CO_2
   26661 g CO_2 = 26.661 Kg CO_2
   1kg = 2.21 lbs
   26.661 Kg CO_2 * 2.21 lbs/1Kg
   =58.92 lbs of CO_2

2. Have the students think about how many lightbulbs they have in their house (or in 1 room of the house), and how often these lights are used (on average). Have the students calculate the cost savings in a year of switching all of these bulbs from incandescent bulbs (60 W) to LED bulbs (8 W). Assume the cost of electricity is \$0.12 per kWh.

   Answer:

   assume: 20 incandescent bulbs (60 W each) in home
   on average, 10 bulbs used 12 hr/day
   10 bulbs used 6 hr/day
   so, total energy used with incandescent bulbs in a year
   10 bulbs × 60W × 12hr/day = 7200 Wh = 7.2 kWh/day
   $\frac{7.2\ kWh}{day} \times \frac{365\ day}{year} = 2,628\ kWh/yr$
   10 bulbs × 60W × 6 hr/day = 3600 Wh = 3.6 kWh/day
   $\frac{3.6\ kWh}{day} \times \frac{365\ day}{yr} = 1,314\ kWh/yr$
   total energy use = 2,628 kWh/yr + 1,314 kWh/yr = 3,942 kWh/yr

   cost of using incandescent bulbs given an electricity rate of \$0.12/kWh
   $\frac{3,942\ kWh}{yr} \times \frac{\$0.12}{kWh} = \$473$ per year
   If you switched all bulbs to 8W LED bulbs (given same usage):
   total energy use:
   10 bulbs × 8W × 12hr/day × 365 days/yr ÷ 1000 W/kW = 350 kWh/yr
   10 bulbs × 8W × 6 hr/day × 365 days/yr ÷ 1000W/kW = 175 kWh/yr
   total energy use with LED's = 525 kWh/yr
   cost @ \$0.12/kWh
   $\frac{525\ kWh}{yr} \times \frac{\$0.12}{kWh} = \$63$ per year
   cost savings: \$473 - \$63 = \$410
   if each LED bulb costs \$5, \$5 × 20 bulbs to replace = \$100
   * still save \$310 even when considering cost of buying all new bulbs

3. Once students have calculated the cost savings of buying more energy efficient lightbulbs, have them calculate how much energy and money would be saved by turning the lights off more often (the energy conservation counterpart activity). Have them compare and discuss how much more savings come from the energy efficiency behavior versus the energy conservation behavior (connecting to activity 1.1).

Connection to Home Energy Audit Homework:

- Now look back on your Excel spreadsheet of from your home energy audit homework. Assuming your data on the use of each of these devices is typical for a given week. Now extrapolate this data out and calculate how much your parents spend on the energy to power these devices per year, and how much carbon dioxide is released into the atmosphere each year. Record these calculations on your spreadsheet
- How can you save on energy use in your house? Are you willing to use any of the devices you collected data on less? Are there any efficiency improvements that can be made with these devices?
- *Extension activity:* Calculate the amount of standby power each of the devices you measured uses. How does the amount of standby electricity consumption compare with the total amount of electricity used? Can you think of ways to reduce the standby electricity use?

Scaling it up – Energy Savings:

- Bring the class back together to decide on a task that will reduce energy usage (examples include changing lightbulbs from incandescent to LED's, driving X fewer miles, taking X fewer minutes in the shower, etc.)
- Have the students calculate how much money they would save if they implemented this behavior by themselves (ex. Each student replaced 1 lightbulb or took a 2-minute faster shower).
- Then, calculate how much energy the whole class would save if every single person in the class did this behavior.
- Then, calculate how much energy the whole school would save if every single person in the school did this behavior.
- Then, calculate how much energy the whole city/town would save if every single person in the city/town did this behavior.
- Then, calculate how much energy the whole state would save if every single person in the state did this behavior.
- Then, calculate how much energy the whole country would save if every single person in the country did this behavior.

Discussion – What these numbers mean:

Once the class has completed the "Scaling it Up" Activity, facilitate a discussion with the class about the magnitude of energy use. Possible questions include:

1. What has surprised you most about quantitatively calculating energy use? Did you have an idea before about how much energy various things used?
2. What is the relationship between your energy use and the larger energy system? Explain.

3. We have done a lot of calculating of how many pounds of carbon dioxide is released due to some of our energy use. Using the visual to the right, try to describe to a partner how big your "box" of carbon dioxide would be for one of your devices (laptop, cell phone charger, TV, etc.).
4. Now try scaling this box up like in the last activity. How easy is this to do? How large would the school's "box" of carbon dioxide be?
5. Does this visual representation make you feel any different about your energy use? Would this be a helpful visual in teaching people about the need for decarbonization and/or energy savings?
6. How would you describe the scale of energy use to your younger brother or sister? What type of comparisons could you use?

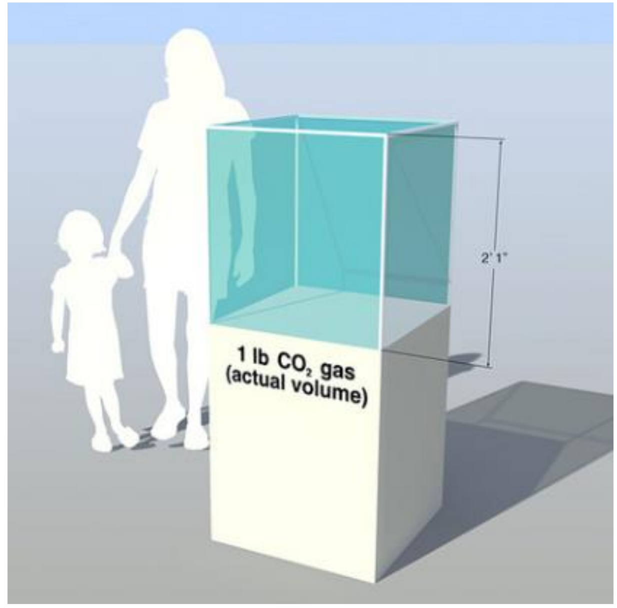


Image from:
https://www.flickr.com/photos/carbonquilt/8229754120

Wrap-Up and Possible Assessments:

- Collect the "Cost of Using Electrical Devices" worksheet to check for student understanding and ability to calculate energy, cost, and carbon dioxide emissions.
- For a homework assignment, the students could repeat the "Scaling Up" exercise with another example, perhaps from home. This would be an excellent formative assessment to check for a student's ability to complete the necessary calculations for determining how much energy a certain behavior uses and how to scale up that energy use.
- An exit slip or informal poll for what (if anything) the students would like to practice more would be very helpful here. The amount of time spent on this activity will vary greatly depending on class, level, and individual students, however, these calculations should not be rushed. If a student is really struggling, it is possible to step back and work on simple unit analysis problems.

The following worksheets are from [The Need Project]

Cost of Using Electrical Devices

Calculate how much it costs to operate the machines in your classroom that you looked at before. You need to know the wattage, the cost of electricity, and the number of hours a week each machine is used.

You can estimate the number of hours the machine is used each week, then multiply by 40 to get the yearly use. We are using 40 weeks for schools, because school buildings aren't used every week of the year. Using the copier as an example, if it is used for ten hours each week, we can find the yearly use like this:

Yearly use = 10 hours/week x 40 weeks/year = 400 hours/year

Remember that electricity is measured in kilowatt-hours. You will need to change the watts to kilowatts. One kilowatt is equal to 1,000 watts. To get kilowatts, you must divide the watts by 1,000. Using the copier as an example, divide like this:

kW = W/1,000

kW = 1,265/1,000 = 1.265

The average **cost of electricity for commercial buildings or schools in the U.S. is about ten cents ($0.10)** a kilowatt-hour. You can use this rate or find out the actual rate from your school's electric bill. Using the average cost of electricity, we can figure out how much it costs to run the copier for a year by using this formula:

Yearly cost	**=**	**Hours used**	**x**	**Kilowatts**	**x**	**Cost of electricity (kWh)**			
Yearly cost	**=**	**400 hours/year**	**x**	**1.265 kW**	**x**	**$0.10/kWh**			
Yearly cost	**=**	**400**	**x**	**1.265**	**x**	**$0.10**	**=**	**$50.60**	

MACHINE OR APPLIANCE	HOURS PER WEEK	HOURS PER YEAR	WATTS (W)	KILOWATTS (kW)	RATE ($/kWh)	ANNUAL COST
Copier	*10*	*400 hours*	*1,265 W*	*1.265 kW*	*$0.10*	*$50.60*

Environmental Impacts

When we breathe, we produce carbon dioxide. When we burn fuels, we produce carbon dioxide too. Carbon dioxide (CO_2) is a greenhouse gas. Greenhouse gases hold heat in the atmosphere. They keep our planet warm enough for us to live, but since the Industrial Revolution we have been producing more carbon dioxide than ever before. Since 1850, the level of CO_2 in the atmosphere has increased more than 44 percent.

Research shows that greenhouse gases are trapping more heat in the atmosphere. Scientists believe this is causing the average temperature of the Earth's atmosphere to rise. They call this global climate change or global warming. Global warming refers to an average increase in the temperature of the atmosphere, which in turn causes changes in climate. A warmer atmosphere may lead to changes in rainfall patterns, a rise in sea level, and a wide range of impacts on plants, wildlife, and humans. When scientists talk about the issue of climate change, their concern is about global warming caused by human activities.

Driving cars and trucks produces carbon dioxide because fuel is burned. Heating homes by burning natural gas, wood, heating oil, or propane produces carbon dioxide too.

Making electricity can also produce carbon dioxide. Some energy sources—such as hydropower, solar, wind, geothermal, and nuclear—do not produce carbon dioxide, because no fuel is burned. About 38.64 percent of our electricity, however, comes from burning coal. Another 30.12 percent comes from burning natural gas, petroleum, and biomass.

On average, every kilowatt-hour of electricity produces 1.23 pounds of carbon dioxide. Let's use this rule to figure out how much carbon dioxide is produced by the machines and electrical devices in your classroom. You can put the figures from the earlier worksheets in the boxes below. Here are the figures for the copier:

CO_2 a year = wattage x hours of use = rate of CO_2/kWh = total pounds of CO_2 per year

CO_2 a year = 1.265 kW x 400 hr/yr x 1.23 lb/kWh = 622.38 lbs/year

MACHINE OR APPLIANCE	KILOWATTS (kW)	HOURS PER YEAR	ANNUAL kWh	RATE OF CO_2/kWh	ANNUAL CO_2 PRODUCED
Copier	*1.265 kW*	*400 hours*	*506 kWh*	*1.23 lbs/kWh*	*622.38 lbs/yr*

Lighting Options

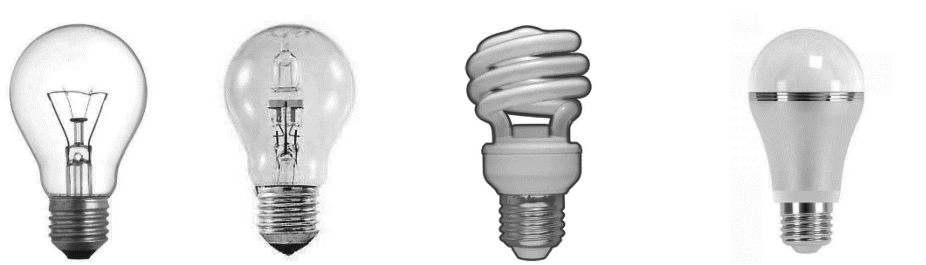
Ten years ago, we used a lot of energy in the form of electricity to make light to be able to see. Thirty percent of the electricity schools used was for lighting, and homes used about 14 percent of their electricity consumption for lighting. That's because homes, schools, and other commercial buildings used a lot of incandescent lighting. These inefficient bulbs were perfected by Thomas Edison in 1879 and didn't change much for the next 125 or more years! These bulbs were surprisingly inefficient, converting up to 90 percent of the electricity they consumed into heat.

The Energy Independence and Security Act of 2007 changed the standards for the efficiency of light bulbs used most often. As of 2014, most general use bulbs must be 30 percent more efficient than traditional, inefficient incandescent bulbs. What do the new standards mean for consumers? The purpose of the new efficiency standards is to give people the same amount of light using less energy. Most incandescent light bulbs have since been phased out and are no longer available for sale. This has resulted in significant energy savings for homes and schools. Newer, efficient lighting now accounts for only 17 percent of the electricity used in schools, and eleven percent used in homes.

There are several lighting choices on the market that meet the new efficiency standards. Energy-saving incandescent, or halogen, bulbs are different than traditional, inefficient incandescent bulbs because they have a capsule around the filament (the wire inside the bulb) filled with halogen gas. This allows the bulbs to last three times longer and use 25 percent less energy.

Compact fluorescent light bulbs (CFLs) provide the same amount of light as incandescent bulbs, but use up to 75 percent less energy and last ten times longer. CFLs produce very little heat. Using CFLs can help cut lighting costs and reduce environmental impacts. Today's CFL bulbs fit almost any socket, produce a warm glow and, unlike earlier models, no longer flicker and dim. CFLs have a small amount of mercury inside and should always be recycled rather than thrown away. Many retailers recycle CFLs for free.

Light emitting diodes, better known as LEDs, are gaining in popularity. Once used mainly for exit signs and power on/off indicators, improved technology and lower prices are enabling LEDs to be used in place of incandescents and CFLs. LEDs are one of the most energy-efficient lighting choices available today. LEDs use 75 percent less energy than traditional incandescents, and have an average lifespan of at least 25,000 hours. The cost of LEDs has dropped in the last five years and may continue to drop. They use even less energy than CFLs, save more electricity, and produce fewer carbon dioxide emissions. The U.S. Department of Energy estimates that widespread adoption of LED lighting by 2027 would reduce lighting electricity demand by 33 percent. This would avoid construction of 40 new power plants.

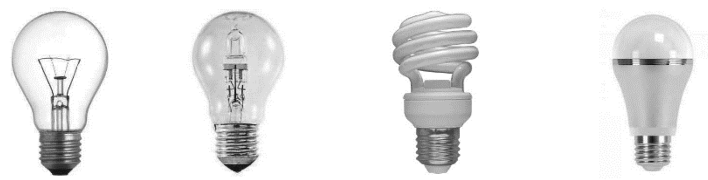


	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
Brightness	850 lumens	850 lumens	850 lumens	850 lumens
Life of Bulb	1,000 hours	3,000 hours	10,000 hours	25,000 hours
Energy Used	60 watts = 0.06 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
Price per Bulb	$0.50	$3.00	$3.00	$8.00

Comparing Light Bulbs

The graphic on the previous page shows four light bulbs that produce the same amount of light. You might use bulbs like these as a bright overhead light. One bulb is an incandescent light bulb (IL), one is a halogen, one is a compact fluorescent light (CFL), and another is a light emitting diode (LED). Which one is the better bargain? Let's do the math and compare the four light bulbs **using the commercial cost of electricity at $0.10/kWh.**

1. Determine how many bulbs you will need to produce 25,000 hours of light by dividing 25,000 by the number of hours each bulb produces light.
2. Multiply the number of bulbs you will need to produce 25,000 hours of light by the price of each bulb. The cost of each bulb has been given to you.
3. Multiply the wattage of the bulbs (using the kW number given) by 25,000 hours to determine kilowatt-hours (kWh) consumed.
4. Multiply the number of kilowatt-hours by the cost per kilowatt-hour to determine the cost of electricity to produce 25,000 hours of light.
5. Add the cost of the bulbs plus the cost of electricity to determine the life cycle cost for each bulb. Which one is the better bargain?
6. Compare the environmental impact of using each type of bulb. Multiply the total kWh consumption by the average amount of carbon dioxide produced by a power plant. This will give you the pounds of carbon dioxide produced over the life of each bulb. Which one has the least environmental impact?



All bulbs provide about 850 lumens of light.

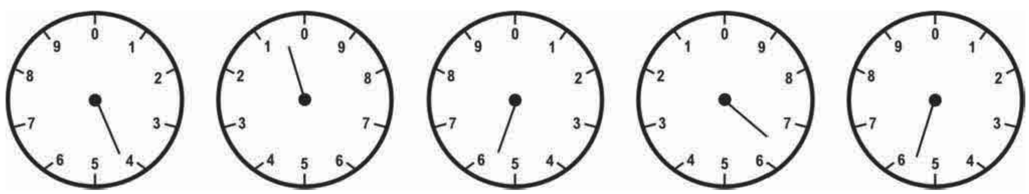
	COST OF BULB	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Life of bulb (how long it will light)	1,000 hours	3,000 hours	10,000 hours	25,000 hours
	Number of bulbs to get 25,000 hours				
x	Price per bulb	$0.50	$3.00	$3.00	$8.00
=	**Cost of bulbs for 25,000 hours of light**				
	COST OF ELECTRICITY	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total Hours	25,000 hours	25,000 hours	25,000 hours	25,000 hours
x	Wattage	60 watts = 0.060 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
=	Total kWh consumption				
x	Price of electricity per kWh	$0.10	$0.10	$0.10	$0.10
=	**Cost of Electricity**				
	LIFE CYCLE COST	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Cost of bulbs				
+	Cost of electricity				
=	**Life cycle cost**				
	ENVIRONMENTAL IMPACT	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total kWh consumption				
x	Pounds (lbs) of carbon dioxide per kWh	1.23 lb/kWh	1.23 lb/kWh	1.23 lb/kWh	1.23 lb/kWh
=	**Pounds of carbon dioxide produced**				

Reading an Electric Meter

An electric company sends electricity to your home or school through a power line. There is a meter at the school to measure the amount of electricity the school uses.

Reading an electric meter is easy. The face of the meter has five dials with the numbers 0 through 9 on each dial. The dials are not alike. On the first dial, the numbers are in a clock-wise direction. On the next meter, the numbers are in the opposite direction, in a counter clock-wise direction. The dials change from clock-wise to counter clock-wise, as shown below. If the pointer is between two numbers, you always record the smaller number. If the pointer is between 9 and 0, record 9, since 0 represents 10 in this instance. Here are two examples with the correct numbers below the dials:

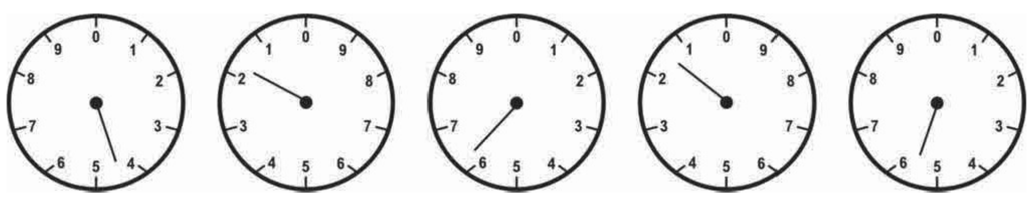
On Monday morning, this was the electric meter reading:



4 0 5 6 5

The total reading is 40,565

On Friday afternoon, this was the electric meter reading:



4 1 6 1 5

The total reading is 41,615

How much electricity was used this week? **Subtract Monday's reading from Friday's reading**:

Friday – Monday = Electricity used

41,615 – 40,565 = 1,050 kilowatt-hours

The electricity is measured in kilowatt-hours. If the power company charges a **school** the **commercial rate** of ten cents ($0.10) for every kilowatt-hour (kWh) of electricity that is used, what is the cost of the electricity that was used during the week?

____________ **kWh X $0.10/kWh = $** ____________________

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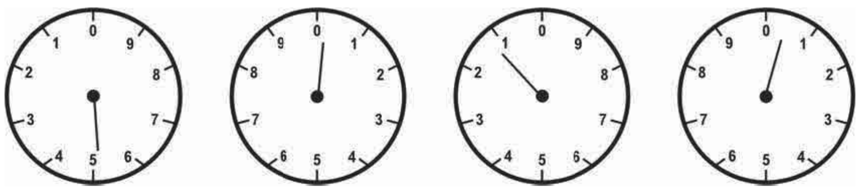
Reading a Natural Gas Meter

A gas company delivers natural gas to a school through an underground pipeline. There is a meter at the school to measure the volume of natural gas that the school uses.

Reading a natural gas meter is much like reading an electric meter. The face of the meter has four dials with the numbers 0 through 9 on each dial. Notice that the dials are not alike. On two dials the numbers are in a clock-wise direction. On the other two, the numbers are in a counter clock-wise direction. Each dial changes from clock-wise to counter clock-wise, as shown below. If the pointer is between two numbers, you always record the smaller number. If the pointer is between 9 and 0, record 9, since 0 represents 10 in this instance. Here are two examples with the correct numbers below the dials:

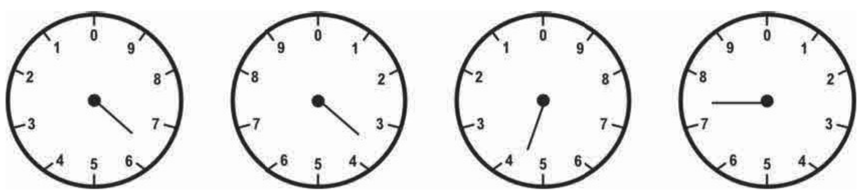
On December 1, this was the natural gas meter reading:



5 0 1 0

The total reading is 5,010

On January 1, this was the natural gas meter reading:



6 3 4 7

The total reading is 6,347

How much gas was used in December? Subtract the December 1st reading from the January 1st reading:

January 1 – December 1 = Electricity used

6,347 – 5,010 = 1,337 Ccf

Natural gas is measured in Cf or cubic feet—a measure of its volume. A cubic foot of natural gas is not much fuel, so most gas meters measure natural gas in hundreds of cubic feet—or Ccf. The gas company measures the natural gas in Ccf, but it charges by the amount of heat or thermal energy in the gas. The thermal energy is measured in therms.

One Ccf of natural gas contains about one therm of heat (1.030 therms in 2014). If the gas company charges $0.89 for a Ccf of gas, **the national average for commercial customers** in 2014, how much did the gas cost for December?

Cost = ____________ **therm X $0.89/Ccf = $** ________________

Unit 1, Activity 4: Energy DIY Project

Energy DIY Project
Lesson by Katie Halpin and Clarkson University Energy Systems Curriculum.

Objectives:

1. Students will be able to identify an energy saving behavior that they can change in their own
2. Students will use problem solving to design a project to save energy
3. Students will be able to make a rough calculation of how much energy their project will save if they implement their design and if everyone in the class implements their design
4. Students will communicate what their design looks like, how it works, and how much energy it will save

Materials:

1. Student worksheets
2. Whiteboards and markers (optional)

Introduction – Energy Saving Projects:

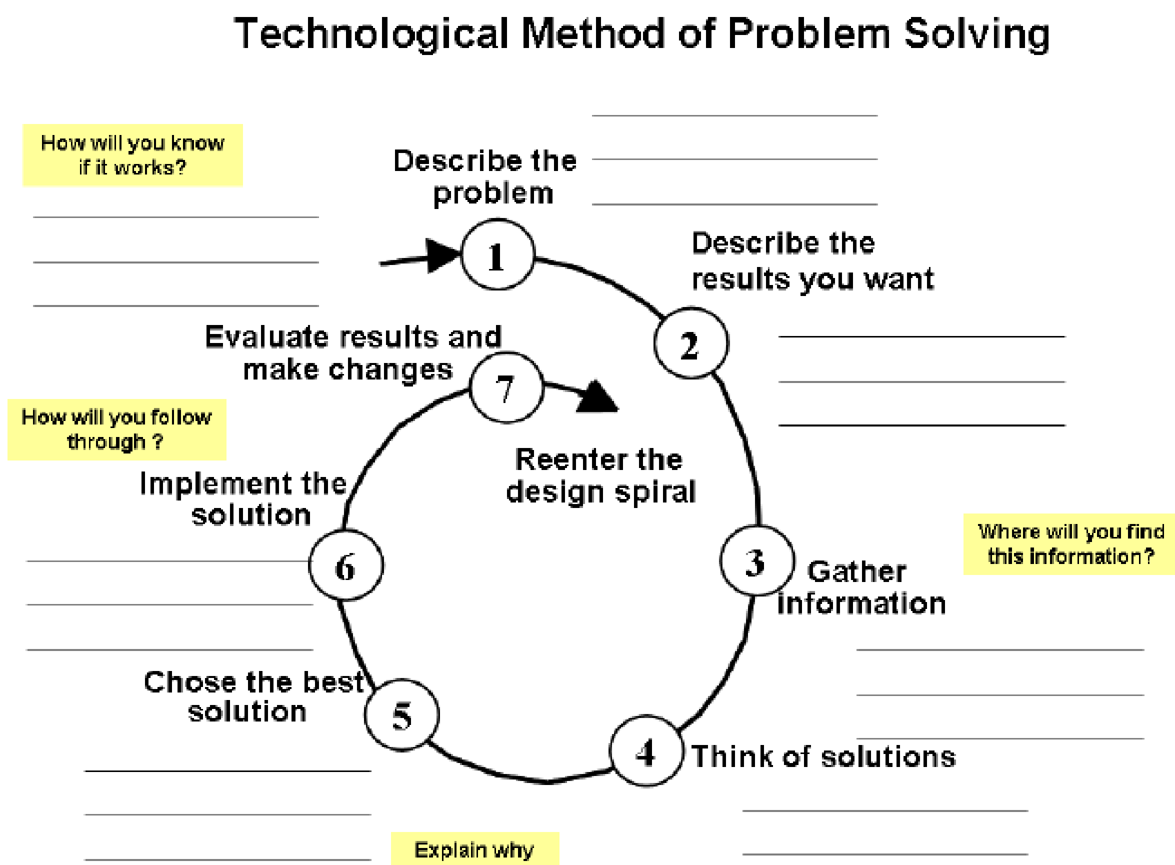
- Now that students have learned about energy efficiency behaviors and energy conservation behaviors, and can calculate how much energy certain things use, the students will come up with DIY projects in their home that will help them save energy.
- Students will begin by brainstorming ideas in groups, however, students will complete these projects on their own.

Activity – Picking an Energy DIY Project:

- Have the students start by brainstorming potential ideas for projects they can design themselves to save energy. Students can work in small groups to generate lists of ideas on whiteboards.
- To refine lists, prompt students to ask the following questions:
    1. Does this design save energy?
    2. How will you calculate the energy this design will save?
    3. Can you realistically incorporate this design into your life for the long term?
- Allow students to come up with their own lists, but example projects could be placing a bottle of water in the back of a toilet bowl to reduce water use during each flush, creating a timer that can be set to time the length of showers, designing a mechanism to remind students to turn off lights, creating a campaign/visual to encourage people to switch incandescent lightbulbs with LED bulbs, etc.
- Once the students have made their lists, they will choose one of their design ideas to implement. Students can fill out the following form about their design.
- Students will create and implement their design. Afterwards, they will present their design and energy saving data to the class.

Student Design Form
(form from Clarkson University Energy Systems Curriculum).

Directions: Fill out the form below based on the energy DIY project idea that you have come up with.



1. Describe your energy DIY project idea.

2. What materials will you need to complete your project?

3. List the tasks and specific steps that need to be done in order to complete your project.

Design Presentations – What Students Have Learned:

- Students will make a presentation about their energy DIY project to share with the class. This presentation can be a PowerPoint, a video, a poster, or another format of your choosing
- Student presentations must include:
    1. A description of their design and how it works to save energy
    2. Calculations to determine how much energy the student will save in a year if they use their design, and how much the entire class will use if everyone uses their design (*Note: student must include what assumptions and sources they made in making these energy calculations)
    3. Drawbacks and limitations to their design idea – how can their design be improved in the future
- Both a teacher rubric and a peer review form are provided below

Wrap-Up and Assessment:

- Collect student design worksheets to assess ideas for feasibility and actual energy saving designs
- Teacher presentation rubric can be used as a summative assessment for the project. Peer review rubrics can be used to assess active listening to other students' presentations.

Teacher Rubric

Criteria	Exceeds Expectations	Meets Expectations	Below Expectations
Description of design and how it saves energy	10	8.5	6
Energy calculations (assumptions, one student, whole class savings)	15	12	9
Drawbacks, limitations, improvements	5	4	3
Presentation style, mechanics, and professionalism	5	4	3
Total Points	/35		

Final Grade:______________________________

Comments:

Peer Review Form

1. Did the presenter clearly explain how their design saves energy and how much energy is saved? What evidence did they use?

2. Is there anything about their project that seems questionable or unreasonable?

3. Do you think their project could be implemented in your life? Why or why not?

4. What suggestions do you have to improve their energy saving design project?

Unit 1 Summative Assessment – Adopting Energy Saving Behaviors

Advocating for a School-Wide Energy Saving Initiative
Lesson by Katie Halpin

Objectives:

1. Students will draw on previous lessons to assess various energy saving behaviors
2. Students will be able to make an argument about which energy saving behavior would be the best option for implementation school-wide

Materials:

1. Enough Rubrics for each guest judge
2. Computer with projection capabilities for student PowerPoints
3. Preferably, pre-load student presentations onto computer for ease of transitions
4. Timer

Assessment Prompt:

Now that we have learned about energy use, conservation, and efficiency, your group will formulate an argument for which energy saving behavior you think our school should adopt in order to save energy and mitigate additional carbon dioxide from entering the atmosphere. You will need to use information about the school's size to *quantitatively* assess how much energy the school will save if the behavior is successfully adopted, how much money the school will save on energy costs, how much they will have to spend to implement the behavior (if applicable), and how much carbon dioxide will *not* end up in the atmosphere due to this change. Furthermore, you must address the social implications and feasibility of this behavior change (will this be a popular change, or will people be angry?). You must include an explanation of why the school should encourage energy savings by implementing this energy-saving behavior. Each group will develop a 15-minute presentation that must address:

- why the school should want to reduce their energy usage
- the economic, environmental, and social considerations of adopting this behavior
- distinguish whether the behavior represents energy conservation or efficiency
- why this type of behavior is the best option for the school

Students will present before a panel of school administrators and stakeholders (volunteer teachers from the school).

Assessment Rubric:

Criteria	Above Average	Average	Below Average	Incomplete
Why should the school want to reduce their energy use and encourage others to reduce their energy use?	Fully formed argument with evidence connecting to scientific principles and class information	Adequate argument that connects to in-class information	Superficial argument with incomplete or unsatisfactory connections to in-class information	Lacks proper argument formation and/or supporting details
Behavior identified and is correctly categorized as conservation or efficiency	Excellent explanation of the behavior, classifications, and differences between classifications	Behavior correctly explained and classified	Behavior identified but not classified/ incorrectly classified	The behavior is not explained and/or classified
Assertion as to why this is the best/most effective behavior to adopt	Fully formed argument with evidence connecting to scientific principles and class information	Adequate argument that connects to some in-class information	Superficial argument with incomplete or unsatisfactory connections to in-class information	Lacks proper argument formation and/or supporting details
Evidence of energy savings with behavior adoption (energy calculations)	Energy comparisons properly done and well-explained	Energy comparisons properly done	Energy comparisons not done properly	Energy comparisons not done
Evidence of economic (costs & savings) considerations	Economic considerations well-explored and explained	Economic considerations mentioned but superficially explained	Economic considerations mentioned but not explained	Economic considerations missing or incomplete
Evidence of environmental (CO_2 reductions) considerations	Environmental considerations well-explored and explained	Environmental considerations mentioned but superficially explained	Environmental considerations mentioned but not explained	Environmental considerations missing or incomplete
Evidence of social (feasibility, popularity) considerations	Social considerations well-explored and explained	Social considerations mentioned but superficially explained	Social considerations mentioned but not explained	Social considerations missing or incomplete
Professionalism and presentation	Presentation is exceptionally well-done, and members contribute equally	Presentation is well done and professional, team members contribute equally	Presentation is lacking professionalism or equal teamwork	Presentation is inadequate, chaotic, and/ or one teammate dominates

Unit 2, Activity 1: Exploring Energy Sources

Where Does my Energy Come From?
Lesson by Katie Halpin and The Need Project (Energy in Society, The Great Energy Debate, and Secondary Energy Infobook Activities).

Objectives:

1. Students will be able to identify which energy sources generate most of the United States' electricity
2. Students will be able to describe the advantages and disadvantages of various energy generation sources
3. Students will be able to elicit some environmental issues associated with energy generation

Materials:

1. Student worksheets
2. Computers with internet access

Introduction – Sources of Energy in the United States:

- Use handout "Electric Connections" (following) to introduce students to the top sources of energy in the United States. **Note: you may want to check the US Energy Information Administration (EIA) website beforehand to make sure that these rankings are still accurate today. If not, a discussion question for after the activity is why might these rankings be changing?*
- After completing the game, have students go to the EIA website, navigate to Indiana's electricity profile, and discover what the top sources of energy are in Indiana (coal, natural gas).

Activity – Advantages and Disadvantages of Energy Sources:

- Use the handout "Great Energy Debate" (following) to highlight the various advantages and disadvantages of the different sources of electricity generation.
- Have the students review the information about the different energy sources first and then, using a jigsaw format, present the most important information about each source to the other students.
- This activity may be done as a whole class, or in smaller groups depending on your class size.
- **Teaching note: it may be helpful to pair this activity with a reading, mini-lecture, etc. that goes over the basic concepts of each of the different types of energy sources and how they work due to the notable misconceptions about energy generation discussed in the literature review. As this information about different energy sources is straightforward and readily available online, this suggested lecture is not included in this curriculum guide. However, quality sources for finding information about energy generation can be found through the EIA or the US Department of Energy.*

Discussion – Interpreting the Energy Debate:

- At the end of the activity, have the students share out facts, advantages, and disadvantages of each of the different energy sources.

- Ask the students which facts surprised them the most? Which facts did they already know?
- Why isn't there one clear "winner" in terms of energy generation – why do we have so many different types of sources?
- Thinking back to our climate change unit, why do we use energy sources that have negative impacts on the environment? Besides fossil fuels emitting carbon dioxide, what are some other environmental issues associated with these different types of energy sources?
- Given that we will eventually need to decarbonize our society, how might we go about replacing fossil fuels with some of these other sources? What are the issues we are seeing with decarbonization?
- What are some other factors (besides environmental considerations) that we need to consider in our choice of energy sources?

Wrap-Up and Assessment:

- For homework, students can complete one or all of the formative assessment activities (following). **Note: it would be helpful to make the "Great Debate" energy source fact sheets available as a resource for students to use in completing these activities. If the students use other sources, encourage them to write down the website to ensure that it is a reliable information source (for example, the EIA website is a great source).*
- To end class, use a formative assessment tool such as questioning, an exit slip, a Kahoot quiz, to address the following:
    1. Which energy source generates the most electricity in the United States? Which generates the second most? Third most?
    2. Why do we have so many different sources of energy? What are some of the issues with coal? Wind? Solar? Nuclear?
    3. If you were in charge, which energy source would you use to generate the US's energy? Why?

All following worksheets are from activities from The Need Project
Electric Connections Worksheet and Instructions:

Electric Connections
GAME INSTRUCTIONS

Almost forty percent of the nation's energy is used to make electricity today. Experts predict that this figure will continue to increase. The U.S. is becoming more dependent on electricity to meet its energy needs as we depend on more technology. To meet the growing demand, many energy sources are used to generate electricity. Some energy sources produce a substantial amount of the electricity we consume, while others produce less than one percent.

Individual Instructions

Your task is to rank the ten sources of energy in order of their contribution to U.S. electricity production. Place a number **one** by the source that provides the **largest amount** of electricity, a number two by the source that provides the second largest, down to a number ten by the one that provides the least amount of electricity. Use critical reasoning skills to determine the order.

Group Instructions

Starting at the top of the list, ask members to contribute any knowledge they have about each energy source. Brainstorm by asking group members questions such as:

- Is this source limited to a certain area of the country?
- Are there any problems or limitations associated with this source?
- Have you ever seen a power plant that uses this particular source of energy?

One person in the group should take notes. Once the group has gone through the list, it should divide the ten energy sources into three levels of importance: the top three most significant energy sources, the middle four moderately significant energy sources, and the bottom three least significant energy sources. The group should then rank the ten sources of energy in order of their contribution to U.S. electricity production.

SOURCES USED TO GENERATE ELECTRICITY

SOURCE	YOUR RANK	GROUP RANK
BIOMASS		
COAL		
GEOTHERMAL		
HYDROPOWER		
NATURAL GAS		
PETROLEUM		
PROPANE		
SOLAR		
URANIUM		
WIND		

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Electric Connections
U.S. ELECTRIC POWER GENERATION SOURCES

SOURCES USED TO GENERATE ELECTRICITY

SOURCE	STATISTICS	RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
BIOMASS	In 2016, biomass produced 62.8 billion kilowatt-hours of electricity, 1.5 percent of the nation's total. Biomass electricity is usually the result of burning wood waste, landfill gas, and solid waste.					
COAL	Over 90 percent of the nation's coal is consumed by electric utility companies to produce electricity. In 2016, coal produced 1,239.1 billion kilowatt-hours of electricity, which was 30.6 percent of the nation's electricity.					
GEOTHERMAL	In 2016, geothermal power plants produced 15.8 billion kilowatt-hours of electricity, mostly from facilities in the western U.S. Geothermal energy produced 0.4 percent of the nation's electricity.					
HYDROPOWER	6.4 percent of U.S. electricity is generated by 2,200 hydro plants nationwide. Hydro plants produced 261.1 billion kilowatt-hours of electricity in 2016. It is the leading renewable energy source used to provide electricity.					
NATURAL GAS	Natural gas produced 1,378.3 billion kilowatt-hours of electricity in 2016, generating 34.0 percent of the nation's electricity. Natural gas is used by turbines to provide electricity during peak hours of demand.					
PETROLEUM	Petroleum provided 0.6 percent of U.S. electricity, generating 24.2 billion kilowatt-hours of electric power in 2016.					
PROPANE	There are no statistics available for propane's contribution to electricity generation. Very little propane is used to produce electricity.					
SOLAR	Solar energy provided 0.9 percent of U.S. electricity in 2016, amounting to 36.5 billion kilowatt-hours of electricity. Electricity was generated by solar thermal systems or photovoltaic arrays.					
URANIUM	99 nuclear reactors provided the nation with 19.9 percent of its electrical energy needs in 2016. Nuclear energy produced 805.7 billion kilowatt-hours of electricity.					
WIND	Wind energy produced 227.0 billion kilowatt-hours of electricity in 2016, providing 5.6 percent of the nation's electricity. Most of the wind-generated electricity is produced in Texas, Iowa, and Oklahoma.					
		ERROR POINTS TOTALS		______		______

Error points are the absolute difference between your ranks and EIA's (disregard plus or minus signs).

Data: Energy Information Administration, Annual Energy Report

SCORING:

0-12 Excellent
13-18 Good
19-24 Average
25-30 Fair
31-36 Poor
37-42 Very Poor

Great Energy Debate Instructions and Sheets:

Teacher Guide

Background

In *Great Energy Debate*, student teams learn about all of the energy sources, then are assigned to represent one specific energy source. Working cooperatively, students develop arguments on the merits of their source over the others.

Objective

Students will be able to list and identify the economic and environmental advantages and disadvantages of the major energy sources.

Concepts

- We use ten major sources of energy in the United States.
- Some energy sources are nonrenewable; others are renewable.
- Energy is used for transportation, heating, cooking, manufacturing, and making electricity.
- Some energy sources affect the environment more than others.
- Some energy sources provide a lot of the energy used in the U.S.; others provide only a small amount.
- Some energy sources provide energy at a low cost; others are more expensive.

Materials

- A set of *Energy Source Debate Sheets* for each team (For younger students, you can use simplified debate sheets found in *Energy in the Balance*, available online at www.NEED.org.)
- A set of YES/NO signs for each of the judges
- *Great Energy Debate Game Board* on page 8, or download an Excel version from www.NEED.org

Preparation

- Decide how many energy sources you will be using, depending upon the number of students in the class or group. For large groups of 30 or more, you can use all ten energy sources. For smaller groups, choose fewer energy sources. Each group should have a minimum of three students.
- Make one copy of each of the *Energy Source Debate Sheets* you will be using for each group.
- If you are using fewer than ten energy sources, make copies of the *Energy Source Debate Sheets* that you are not using. Complete these sheets as a class after you introduce the activity. This will ensure that the students understand the concepts of advantages/disadvantages and learn about all of the energy sources.
- Ask three colleagues, school administrators, community leaders, or parents to serve as judges for the debate. If volunteers are not available, you may assign three students to serve as judges.
- Make sets of YES/NO cards for the judges.

Grade Levels

- Intermediate, grades 6-8
- Secondary, grades 9-12

Time

Two or three 45-minute class periods (If you have limited time, see *Alternate Procedure* on page 7.)

Additional Resources

Use NEED's *Energy Infobooks*, available for free download at www.NEED.org, for more in-depth information about each energy source. *Energy Infobooks* are available at the intermediate and secondary levels.

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✔ Procedure

Step One: Introduce Unit to the Class

- Introduce the *Great Energy Debate* to the class, using the concepts as a guide.

Step Two: Monitor Group Work

- Once students are in their groups, explain the procedure. Answer any questions they have about the activity. If you are not using all ten sources, use the extra debate sheets you are not using to explain the procedure. Have the groups complete the sheet for their assigned source first. This should take about five minutes.
- Have the groups complete the sheets for the other groups' energy sources. This should take about twenty minutes.

Step Three: Debate

- Begin the game by giving the teams the following instructions:
  - The object of this game is to be the first team to reach the top of the game board. The game is played in rounds. Each team is given the opportunity to move its token up by stating an advantage of its energy source. You may instead choose to move an opponent's token down by stating a disadvantage of the opponent's energy source.
  - Teams will present their advantages or opponent disadvantages to a panel of judges. An opposing team can object to the presented statement. The opposing team must convince the judges that the statement is not an advantage. The team that stated the advantage will then have the opportunity to defend its position. The judges may vote in favor of the defending team or presenting team. If they agree with the presenting team's stated advantage, that team will move up one. If they vote in favor of the defending team, the defending team moves up one position and the presenting team moves down one space. Or, the judges may decide the statement is just a fact. In this case, the defending team stays in its original position.
  - If a team states a disadvantage to try to move an opposing team down, then the opposing team can defend itself without penalty. The stating team does lose position if judges side with the opposing team.
- Ask the first team to give an advantage or disadvantage. Action continues until one team reaches the top line, until time is called, or until each team has had the opportunity to begin a round.
- DAY ONE—complete the first round.
- DAY TWO—finish the remaining rounds.

Step Four: Interpret the Debate Results

- At the conclusion of the debate, point out that all sources of energy have advantages and disadvantages. Ask the class the following questions:
  - Why isn't there an obvious winner in this debate?
  - Even if the debate continued, would there be a winner? Why or why not?
  - Why do we use energy sources that have negative impacts on the environment?
  - What are some other factors that we need to consider in our choice of energy sources?

Great Energy Debate - Alternate Procedure

Preparation

- Make one set of *Energy Source Debate Sheets* for each student, plus an additional set for each group.
- Make a copy of the *Great Energy Debate Game Board,* or download the Excel file from www.NEED.org to project.
- Make a copy of one of the debate sheets to project and explain the procedure, if necessary.
- Make sets of YES/NO cards for the judges.

✔Procedure

Step One: Introduce Unit to the Class

- Introduce the *Great Energy Debate* to the class, using the concepts as a guide.
- Distribute one set of debate sheets to each student. Explain the procedure for completing the sheets, projecting a sample, if necessary.
- Instruct the students to complete all of the debate sheets individually as classwork or homework.

Step Two: Monitor Group Work

- Decide who will be in each of the groups. If your students are not used to working in groups, you may want to give them guidelines for group work.
- Place students into groups. Distribute a set of debate sheets to each group. Have the students complete the debate sheets as a group, using their individual sheets as guides. This should take about thirty minutes. Let students know which source they will tackle as a group.

Step Three: Debate

- Use the instructions set forth under Step Three on page 6.

Step Four: Interpret the Debate Results

- Use the instructions set forth under Step Four on page 6.

SAMPLE

Coal

	RELEVANT		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Coal is one of the most abundant fuels in the United States. We have over a 280 year supply based on the current rate of consumption.		x	
2. Although coal is still being formed today, we use it thousands of times faster than it is formed.			x
3. Coal generates 33 percent of the electricity in the U.S.	x		

Great Energy Debate Game Board

	Biomass	Coal	Geothermal	Hydropower	Natural Gas	Petroleum	Propane	Solar	Uranium	Wind
ADVANTAGES										
START HERE										
DISADVANTAGES										

Biomass

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Biomass is a source of energy from plant materials and animal waste.			
2. Biomass is a renewable energy source; we can grow more biomass.			
3. Biomass is difficult to store and transport because it decays.			
4. As biomass decays, more of its energy is available for use as fuel.			
5. Biomass was the first source of energy harvested and used by humans.			
6. Some of the carbon dioxide created by burning biomass can be absorbed by planting new biomass.			
7. The amount of energy stored in biomass is less than the amount of energy stored in an equivalent weight of a fossil fuel.			
8. Biomass can be used as a fuel because it captures and stores radiant energy from the sun through the process of photosynthesis.			
9. Less than 3% of American homes use biomass (burn wood) as their only heat source.			
10. Biomass is abundant and can be produced almost everywhere in the U.S.			
11. Burning biomass can produce odors and emissions.			
12. Burning biomass in a waste-to-energy plant produces a small amount of U.S. electricity.			
13. Biomass provides 4.9 percent of the nation's total energy demand.			
14. Today, about 44 percent of biomass energy comes from wood.			
15. The pulp and paper industries use waste wood to generate steam and electricity, meeting over half of their own needs.			
16. Biomass can be made into ethanol and biodiesel, transportation fuels that are cleaner-burning than unleaded gasoline and traditional diesel.			
17. Alcohol fuels made from biomass can be domestically produced.			
18. Mixing 10 percent ethanol with gasoline produces E10, a cleaner-burning fuel used nationwide.			
19. Burning biomass in a waste-to-energy plant reduces the amount of garbage sent to landfills.			
20. Waste-to-energy plants use scrubbers and other technologies to reduce emissions and odors.			

Coal

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Coal is one of the most abundant fuels in the United States. We have over a 280 year supply based on the current rate of consumption.			
2. Although coal is still being formed today, we use it thousands of times faster than it is formed.			
3. Coal generates 33 percent of the electricity in the U.S.			
4. The U.S. exports about 8.3 percent of the coal it produces to other countries.			
5. Coal has been burned to cook food and heat living spaces and water for thousands of years.			
6. Today, over 90 percent of the coal consumed in the U.S. is used by the electric power sector to generate electricity.			
7. When coal is burned, carbon dioxide, sulfur dioxide, nitrous oxide, and other pollutants are produced.			
8. To remove coal buried deep in the earth, mine shafts are constructed to bring the coal to the surface.			
9. An easier way to mine coal near the earth's surface is to remove the layers of earth to uncover the coal. This is called surface mining.			
10. Large amounts of land are disturbed in the process of surface mining.			
11. Surface mines can be restored to grasslands or parks after the coal is removed.			
12. About one-third of the nation's coal is produced from underground mines.			
13. The water that filters through abandoned mines can pick up chemicals that pollute the water if the mines are not closed correctly.			
14. Coal is used to smelt iron into steel and by the paper and building supply industries.			
15. Coal can be turned into a gas to make it burn cleaner. This process is expensive.			
16. Coal mining can be dangerous for miners due to gases and explosion hazards.			
17. Ash from coal plants can be recycled and used for cement additives, roadway materials, and even in habitat restoration for oysters.			
18. Some cleaner coal technologies require less coal to produce the same amount of electricity.			
19. The methane gas that is found around much of the coal in the U.S. is a valuable resource.			
20. The electricity industry uses items like scrubbers to reduce harmful emissions from coal plants.			

Geothermal

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Geothermal energy comes from heat within the Earth.			
2. Examples of geothermal energy are hot springs, volcanoes, and geysers.			
3. Geothermal energy is generated in Earth's core, which is made of magma (molten iron) surrounding a solid, mostly iron core.			
4. Red hot temperatures are maintained inside the Earth because of the slow decay of radioactive particles found in all rocks, and the immense pressure on the core.			
5. Geothermal energy is renewable. The hot water used by power plants is replenished by precipitation and the geothermal heat is continually produced.			
6. Wells can be built to pump super-heated water to the surface.			
7. Geothermal energy is used to produce electricity and to heat and cool buildings.			
8. Geothermal energy was used by ancient people for heating and bathing. Hot springs are said to have therapeutic effects today.			
9. In 1904, the Italians first used steam erupting from the earth to power a turbine generator.			
10. Dry steam reservoirs are the most efficient for producing electricity, but they are very rare.			
11. The United States generates more electricity from geothermal than any other country in the world.			
12. High temperature geothermal resources capable of producing electricity are not economically available in all parts of the nation.			
13. The most active geothermal resources are found along major tectonic plate boundaries, where magma comes very near Earth's surface.			
14. Geothermal energy produces less than one percent of the electricity consumed in the nation today.			
15. Geothermal energy does little damage to the environment because geothermal power plants sit on or near the geothermal reservoirs and do not burn any fuel.			
16. Geothermal steam and hot water contain traces of hydrogen sulfide and other gases, as well as chemicals that are harmful at high concentrations.			
17. The gases and chemicals from geothermal power plants are usually reinjected into the Earth.			
18. The temperature of the earth a few feet underground remains constant year round—about 52 degrees Fahrenheit in moderate climates.			
19. Low temperature geothermal energy is available everywhere in the U.S. for heating and cooling homes.			
20. Geothermal heat pumps use the Earth's constant temperature as an energy source to heat buildings in winter and cool them in summer.			

Hydropower

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Moving water has been used as a source of energy for thousands of years.			
2. Hydropower is considered one of the cleanest and cheapest energy sources in widespread use today.			
3. Moving water is a renewable energy source.			
4. Moving water can turn a turbine to generate electricity.			
5. Hydropower was first used to turn water wheels to grind grain.			
6. Hydroelectric power is reliable because dams can be built to store water. Controlling the flow of the stored water allows a power plant to operate in all weather conditions and at times of greater electrical demand.			
7. About 5-10 percent of total U.S. electricity is generated by hydropower plants, depending on the amount of rainfall.			
8. Hydropower provides the U.S. with about 2.4 percent of our total energy consumption.			
9. In the last 60 years, hydropower production in the United States has increased by 63 percent.			
10. The nation's largest producer of hydroelectric power is the Federal Government, which operates many large dams and power plants.			
11. There are about 2,200 hydroelectric power dams in the U.S. today.			
12. There are about 81,800 dams that do not have generating plants on them.			
13. New construction and improvements at existing hydropower plants could increase our hydroelectric capacity by 30,000 to 60,000 MW by 2025.			
14. When a hydropower dam is built, thousands of acres of nearby land are flooded to create a reservoir.			
15. Projects using wave and tidal energy to generate electricity are being tested and used in a few locations in the U.S. and around the world.			
16. Dams can disturb the migration and spawning of fish populations in the river.			
17. Dams can alter the natural flow of the river and change the amount of water that reaches communities downstream.			
18. Reservoirs that result from construction of a dam are often developed for recreational purposes, such as boating and fishing.			
19. The use of conventional hydropower in the U.S. is not expected to increase significantly in the future, but wave and tidal projects are expected to increase.			
20. Some countries use hydropower as their main source to produce electricity. Norway produces 96 percent of its electricity from hydropower.			

Natural Gas

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Natural gas was formed from the decomposition of tiny sea plants and animals that lived hundreds of millions of years ago.			
2. Natural gas is mostly made of a chemical called methane.			
3. Natural gas is odorless; an odorant called mercaptan is added for safety.			
4. Natural gas can be processed and other products, like propane and the materials in plastics, can be recovered from it.			
5. Natural gas is considered to be the cleanest-burning fossil fuel. It produces almost no sulfur or nitrogen oxides.			
6. Natural gas and petroleum are often found together in underground deposits.			
7. In the past, oil drillers were not interested in the natural gas that was found at the site of an oil well. Today, it is as valuable as the oil.			
8. The invention of high pressure pipelines has made it possible to transport natural gas all over the U.S.			
9. Leaks can occur in natural gas pipelines. Fires and explosions can result from these leaks if proper safety precautions are not taken.			
10. About 5.5 percent of the natural gas we produce comes from federal offshore wells in the Gulf of Mexico.			
11. Natural gas is a nonrenewable resource.			
12. Today, the U.S. has a large supply of natural gas. There are also large reserves of natural gas offshore, on the outer continental shelf, and in the Gulf of Mexico.			
13. Natural gas is used almost equally by homes and businesses, industry, and for electric power generation.			
14. Natural gas can be used as a cleaner-burning transportation fuel.			
15. Natural gas supplies will likely last about 93 years at today's prices and consumption rate.			
16. Natural gas accounts for 29.0 percent of total U.S. energy consumption.			
17. If a higher price is charged for natural gas, supplies could last as long as 200 years.			
18. Roughly half of the homes in the U.S. use natural gas as their main heating fuel.			
19. Natural gas is used to produce peak load electricity because natural gas furnaces can be brought on line and shut down quickly and efficiently to generate steam for electricity.			
20. Burning methane produces carbon dioxide. Both methane and carbon dioxide are greenhouse gases that trap heat energy. Increasing the levels of greenhouse gases in the atmosphere can affect the global climate.			

Petroleum

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. The word petroleum is derived from the word *petro,* meaning rock, and the word *oleum*, meaning oil.			
2. Petroleum deposits were formed over hundreds of millions of years from the remains of marine plants and animals.			
3. Petroleum is a nonrenewable energy source.			
4. Oil deposits are found in many areas, onshore and offshore.			
5. The U.S. imports about 48 percent of the petroleum it uses from other countries.			
6. The U.S. has large petroleum deposits in Alaska and offshore.			
7. Many offshore resources are off-limits to development due to state and federal regulations.			
8. One-sixth of the oil the U.S. produces comes from offshore wells, mostly in the Gulf of Mexico.			
9. Petroleum straight from the well—crude oil—is not usable. It must be refined into gasoline and other products.			
10. Petroleum refining uses the boiling points of different hydrocarbon molecules to separate them for different uses.			
11. We get many fuels from refining petroleum—gasoline, kerosene, jet fuel—that can be burned to produce heat, light, electricity, or motion.			
12. Many chemical products from petroleum can be used to make plastics, medicines, fertilizers, and other products.			
13. When petroleum products are burned, harmful emissions are produced.			
14. To protect the environment, oil drilling and production are regulated by federal and state governments.			
15. Oil is transported by pipeline, truck, or tanker to where it is refined and/or used.			
16. If oil is spilled into the water or onto the land, it can cause damage to the environment.			
17. Petroleum products are efficient, economical transportation fuels. Most transportation in the U.S. is fueled by petroleum products.			
18. Today, gasoline powered vehicles produce fewer emissions than they used to, due to advances in engine design and fuel formulation.			
19. Petroleum is the leading source of energy in the U.S., supplying 36.6 percent of the energy used in the U.S.			
20. At current rates of consumption, there is at least a 23 year worldwide reserve of petroleum.			

Propane

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. About half of the propane we use comes from natural gas processing, and half from petroleum refining. We import about 11 percent of the propane we use.			
2. Under normal conditions propane is a gas, but under moderate pressure or low temperature, propane becomes a liquid.			
3. Propane is stored as a liquid in pressurized tanks because it takes up 1/270 of the space it occupies as a gas, and is very portable.			
4. Propane becomes a gas when it is released from the pressure in the tank. As a gas, it is used to fuel appliances.			
5. Like natural gas, propane is colorless and odorless. An odorant called mercaptan is added as a safety measure.			
6. Propane is a nonrenewable energy source.			
7. Propane is a cleaner-burning fossil fuel.			
8. Propane is moved through pipelines to distribution terminals.			
9. Propane is taken from distribution terminals to bulk plants by trains, trucks, barges, and supertankers. Local dealers fill their small tank trucks and distribute it to their clients.			
10. Propane is mostly used in rural areas that do not have reliable access to utilities. Homes and businesses use it for heating, hot water, cooking, and clothes drying.			
11. Farms rely on propane to dry crops, power tractors, heat greenhouses, and warm chicken houses.			
12. Propane is also used by taxicab companies, government agencies, and school districts to fuel their vehicles.			
13. As a vehicle fuel, propane is cleaner-burning than petroleum and leaves car engines free of deposits. Engines fueled by propane also have fewer emissions.			
14. There is a slight drop in miles per gallon when propane is used to fuel vehicles instead of gasoline.			
15. Propane is not widely used as a transportation fuel because it is not as conveniently available as gasoline or diesel.			
16. An automobile engine must be adjusted to use propane.			
17. Propane gas is heavier than air and can explode if the propane is ignited.			
18. Propane is more expensive than natural gas, heating oil, or kerosene.			
19. Propane is often used to power indoor vehicles such as forklifts.			
20. Propane supplies and price are tied to oil and natural gas supplies and costs.			

Solar

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. The sun radiates more energy in one day than the world can use in a year.			
2. The sun is a star made up mostly of hydrogen and helium gas. It produces radiant energy in a process called nuclear fusion.			
3. Harnessing radiant energy from the sun is difficult because the energy that reaches the Earth is very spread out.			
4. Only a small part of the solar energy radiated ever reaches the Earth.			
5. It takes the sun's energy just over eight minutes to travel 93 million miles to the Earth.			
6. Solar energy is a renewable energy source.			
7. Solar energy is used to heat passive solar buildings and water and to generate about one percent of U.S. electricity.			
8. The amount of solar energy reaching an area depends on the time of day, season of the year, cloud coverage, and geographic location.			
9. Solar water heaters can reduce energy bills by half when installed.			
10. A solar collector can be used to capture sunlight and change it into usable heat energy.			
11. An active solar home in the Northern Hemisphere uses special equipment on the south side of the building to absorb sunlight and change it into thermal energy. Air or water flows through the collector and is warmed by the energy inside.			
12. Passive solar homes do not depend on mechanical equipment to transform radiant energy into thermal energy.			
13. Photovoltaic cells can convert radiant energy from the sun directly into electricity.			
14. Concentrated solar power technology uses reflective mirrors to focus solar energy, producing high temperatures and generating electricity.			
15. Photovoltaic—or PV—systems have a long payback period because of their initial cost.			
16. PV cells are used to power homes, roadside telephones, calculators, and toys, and work well for items in remote locations.			
17. Crystalline silicon PV cells convert about 16 percent of the energy they receive into electricity.			
18. Electricity from PV cells has a cost range of $0.12-0.30/kWh. The average cost of electricity (generated mostly from fossil fuels) in the U.S. today is about $0.127 cents/kWh.			
19. Large solar systems can take up a large amount of land or can be placed on large, flat roofs.			
20. Solar energy does not pollute the air.			

Uranium

	RELEVANCE		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. In 1939, scientists discovered that certain atoms could be split. The splitting of these atoms releases a great amount of energy.			
2. Ninety-nine nuclear power reactors at 61 plants operate in the U.S.			
3. Nuclear plants provide 19.4 percent of the electricity generated in the U.S.			
4. A nuclear reactor can supply a large amount of energy using a very small amount of fuel.			
5. The construction of nuclear power plants is very expensive compared to fossil fuel plants.			
6. Nuclear reactors do not burn uranium or fuel to generate electrical power. They split the uranium atoms—so their emissions are minimal.			
7. Uranium is easy to transport.			
8. Uranium is inexpensive.			
9. The U.S. has abundant supplies of uranium. However, we import most of the uranium used in power plants because it is cheaper than mining it.			
10. Nuclear power plants produce electricity by heating water into steam in the same way as fossil fuel plants.			
11. Workers at nuclear power plants receive less radiation from the plant than they do from other sources like medical x-rays.			
12. Some parts of reactors become radioactive after they have been used.			
13. Radioactive waste from nuclear power plants is stored underground in spent fuel pools or dry cask containers at the plant sites.			
14. Uranium has a very high energy density, producing a large amount of energy from a small amount of mass or space.			
15. Uranium is a nonrenewable energy source.			
16. A nuclear power plant produces a lot of waste heat. If this heat is put into a moving water system, the water temperature can increase.			
17. The main health risk from a nuclear power plant is potential radiation exposure.			
18. Nuclear power plants in the U.S. are highly regulated.			
19. An accident at a nuclear power plant could cause widespread damage if people or the environment were exposed to high levels of radioactivity.			
20. There has been renewed interest in nuclear power in the U.S. in the last few years as concern over global climate change has increased.			

Wind

	Relevance		
	IT'S A FACT	ADVANTAGE	DISADVANTAGE
1. Wind is air in motion caused by the uneven heating of the Earth's surface by the sun.			
2. Wind turbines do not cause air or water pollution because no fuel is burned to generate electricity.			
3. Wind is a renewable source of energy.			
4. Wind turbines operate on average about three-fourths of the time, though not always at capacity.			
5. For hundreds of years, windmills were used to grind wheat and corn, to pump water, and to cut wood at sawmills.			
6. Wind turbines have turning blades to harness the wind's kinetic energy. The blades are connected to drive shafts that turn generators to make electricity.			
7. Wind plants can typically convert 30-40 percent of the wind's kinetic energy into electricity.			
8. When the wind is not blowing, other sources of energy must be used to generate needed electricity.			
9. The locations of wind farms are carefully planned—good sites include the tops of smooth, rounded hills, open plains or shorelines, and mountain gaps.			
10. Offshore turbines produce more electricity than turbines on land.			
11. Wind power plants, or wind farms, are clusters of several wind turbines spread over a large area. The land around the wind turbines can also be used for grazing or growing crops.			
12. Wind farms are often owned and operated by business people who sell the electricity to utility companies because they can be expensive to build.			
13. Wind turbines can be used in remote areas that do not otherwise have access to electricity.			
14. Almost every state has the capacity to produce electricity from wind.			
15. The U.S. generates about 14 percent of the world's wind energy.			
16. Older wind turbines are very noisy; new technologies have eliminated most noise.			
17. Wind turbines can injure birds or bats that fly into the spinning blades.			
18. It costs about \$0.03 to \$0.05/kWh to produce electricity from wind power plants. The average cost of electricity (generated mostly from fossil fuels) in the U.S. today is about \$0.127 cents/kWh.			
19. Wind turbines provide the U.S. with enough electricity to power over 17 million homes.			
20. Offshore turbines cost more money to build and operate than turbines on land.			

Formative Assessment Student Sheets:

Biomass

Description of biomass:

Renewable or nonrenewable:

Description of photosynthesis:

Ways we turn biomass into energy we can use:

Who uses biomass and for what purposes:

Effect of using biomass on the environment:

Important facts about biomass:

Coal

Description of coal:

Renewable or nonrenewable:

Where coal is located and how we recover it:

Ways we turn coal into energy we can use:

Who uses coal and for what purposes:

Effect of using coal on the environment:

Important facts about coal:

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Geothermal

Description of geothermal energy:

Renewable or nonrenewable:

Where geothermal resources are located and how we recover them:

Ways we turn geothermal energy into energy we can use:

Who uses geothermal energy and for what purposes:

Effect of using geothermal energy on the environment:

Important facts about geothermal energy:

Hydropower

Description of hydropower:

Renewable or nonrenewable:

Description of the water cycle:

Ways we turn hydropower into energy we can use:

Who uses hydropower and for what purposes:

Effect of using hydropower on the environment:

Important facts about hydropower:

Natural Gas

Description of natural gas:

Renewable or nonrenewable:

Where natural gas is located and how we recover it:

Ways we turn natural gas into energy we can use:

Who uses natural gas and for what purposes:

Effect of using natural gas on the environment:

Important facts about natural gas:

Petroleum

Description of petroleum:

Renewable or nonrenewable:

Where petroleum is located and how we recover it:

Ways we turn petroleum into energy we can use:

Who uses petroleum and for what purposes:

Effect of using petroleum on the environment:

Important facts about petroleum:

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Propane

Description of propane:

Renewable or nonrenewable:

Where propane is located and how we recover it:

Ways we turn propane into energy we can use:

Who uses propane and for what purposes:

Effect of using propane on the environment:

Important facts about propane:

Solar

Description of solar energy:

Renewable or nonrenewable:

How solar energy is produced:

Ways we turn solar energy into energy we can use:

Who uses solar energy and for what purposes:

Effect of using solar energy on the environment:

Important facts about solar energy:

Uranium (Nuclear)

Description of uranium:

Renewable or nonrenewable:

Where uranium is located and how we recover it:

Ways we turn uranium into energy we can use:

Who uses uranium (nuclear energy) and for what purposes:

Effect of using uranium (nuclear energy) on the environment:

Important facts about uranium (nuclear energy):

Wind

Description of wind energy:

Renewable or nonrenewable:

Where wind energy is located and how we recover it:

Ways we turn wind into energy we can use:

Who uses wind and for what purposes:

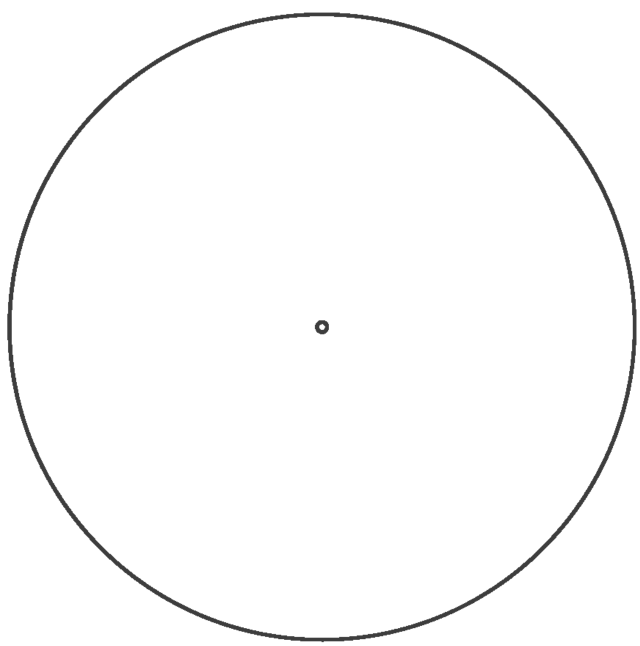
Effect of using wind on the environment:

Important facts about wind:

Renewables and Nonrenewables

Convert the quads into percentages and make a pie chart showing how much U.S. energy in 2015 came from renewable sources and how much came from nonrenewable sources. Round to the nearest hundredth.
(Q = quad or quadrillion British thermal units)

Petroleum*	**35.603 Q = ______________ %**
Natural Gas*	**28.196 Q = ______________ %**
Coal	**15.549 Q = ______________ %**
Uranium	**8.337 Q = ______________ %**
Biomass	**4.734 Q = ______________ %**
Hydropower	**2.321 Q = ______________ %**
Wind	**1.777 Q = ______________ %**
Geothermal and Solar	**0.638 Q = ______________ %**
Total Quad BTUs	**________ = ______________ %**



*** Includes Propane**

How We Use Our Energy Sources

In the boxes, describe the main uses of each energy source. Put a * beside the most important use. Some sources may be used in only one or two ways.

	TRANSPORTATION	MAKE PRODUCTS	HEATING/COOLING	LIGHTING	MAKE ELECTRICITY
U 235					

Formative Assessment Answer Sheets:

Biomass

Description of biomass:
Any organic material that can be used for its energy content—wood, garbage, yard waste, crop waste, animal waste, even human waste.

Renewable or nonrenewable:
Renewable

Description of photosynthesis:
The process by which radiant energy from the sun is converted to glucose, or sugar. This glucose stores chemical energy within the plant.

Ways we turn biomass into energy we can use:
Burning to produce heat, fermentation into alcohol fuel (ethanol), bacterial decay into methane, conversion to gas or liquid fuels by addition of heat or chemicals.

Who uses biomass and for what purposes:
Industry burns waste wood to make products, homes burn wood for heat, waste-to-energy plants burn organic waste products to produce electricity, and ethanol and biodiesel are used as a transportation fuels.

Effect of using biomass on the environment:
Burning biomass can produce air pollution and does produce carbon dioxide, a greenhouse gas. It can also produce odors. Burning biomass is cleaner than burning fossil fuels. Growing plants to use as biomass fuels removes carbon dioxide from the atmosphere.

Important facts about biomass:
Biomass gets its energy from the sun through the process of photosynthesis.

Using biomass reduces the amount of organic material placed in landfills.

Fast-growing crops can be grown for their energy content.

Using biomass does not contribute as much to the greenhouse effect as fossil fuels. The amount of carbon dioxide produced by equipment to process biofuels is offset somewhat by the amount taken in during growth.

Coal

Description of coal:
Coal is a black, solid hydrocarbon (fossil fuel) formed from the remains of ancient plants in swamps millions to hundreds of millions of years ago.

Renewable or nonrenewable:
Nonrenewable

Where coal is located and how we recover it:
Coal is located underground in many areas of the country. Shallow seams are surface mined. Coal buried deep is reached through underground mine shafts.

Ways we turn coal into energy we can use:
Most coal is burned to produce thermal energy.

Who uses coal and for what purposes:
Power plants burn most of the coal to produce electricity. Industries also burn coal to make products, especially steel and iron.

Effect of using coal on the environment:
Burning coal contributes emissions of CO_2 and other pollution, and can cause acid rain. Burning coal also produces carbon dioxide, a greenhouse gas.

Important facts about coal:
Coal produces about 33.08 percent of the electricity in the U.S.

The U.S. has the largest reserves of coal in the world.

Coal is found in Appalachian states and some western states.

Wyoming, West Virginia, Kentucky, Illinois, and Pennsylvania are the top coal producing states.

Coal is transported mainly by train and barge. Transporting coal is a huge expense.

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Geothermal

Description of geothermal energy:
Geothermal energy is heat produced in the Earth's core by the slow decay of naturally-occurring radioactive particles.

Renewable or nonrenewable:
Renewable

Where geothermal resources are located and how we recover them:
Low temperature resources are almost everywhere a few feet underground. High temperature resources are found along major plate boundaries, especially around the Ring of Fire in the Pacific Ocean.

Ways we turn geothermal energy into energy we can use:
We can drill wells to reach high temperature resources, or lay pipes filled with fluid underground. Some geothermal resources come out of the ground naturally, and we can pipe it to where it's needed.

Who uses geothermal energy and for what purposes:
Power plants use geothermal steam to produce electricity. Homes and businesses use the hot water and steam for thermal energy.

Effect of using geothermal energy on the environment:
There is very little environmental effect.

Important facts about geothermal energy:
Earth is made of layers—an inner core of iron, an outer core of magma (melted rock), a mantle of magma and rock, and a crust. The crust is not a solid piece, but giant plates of land that move. Along the edges of the plates, geothermal resources tend to come to the surface.

Hydropower

Description of hydropower:
Hydropower is the force of moving water caused by gravity.

Renewable or nonrenewable:
Renewable

Description of the water cycle:
The sun shines onto the Earth, evaporating the water in oceans, rivers, and lakes. The water vapor rises into the atmosphere and forms clouds. The water vapor condenses and falls to Earth as precipitation.

Ways we turn hydropower into energy we can use:
We can harness the energy in flowing water by damming rivers and using waterfalls.

Who uses hydropower and for what purposes:
Electric utilities use hydropower dams to turn the energy in flowing water into electricity.

Effect of using hydropower on the environment:
Dams can flood land and disrupt animal and fish habitats. Hydropower doesn't pollute the air, but it can churn up sediments in the water.

Important facts about hydropower:
Hydropower dams are the cheapest and cleanest way to produce electricity.

There are few places in the U.S. where new dams can be built.

Some existing dams could have turbines installed to produce electricity.

Natural Gas

Description of natural gas:
Natural gas is a colorless, odorless gas formed hundreds of millions of years ago from tiny sea plants and animals. It is a fossil fuel.

Renewable or nonrenewable:
Nonrenewable, although methane produced from landfill gas is classified as renewable.

Where natural gas is located and how we recover it:
Natural gas is located in underground rock formations in sedimentary basins. We drill wells to reach it and pipe it from the ground.

Ways we turn natural gas into energy we can use:
We burn natural gas to produce heat and generate electricity.

Who uses natural gas and for what purposes:
Power plants burn natural gas to produce electricity. Industry burns natural gas to manufacture products. Homes and businesses burn natural gas to heat buildings and water, and for cooking.

Effect of using natural gas on the environment:
Natural gas is a cleaner burning fossil fuel, but it produces some air pollution and carbon dioxide, a greenhouse gas.

Important facts about natural gas:
Mercaptan, an odorant that smells like rotten eggs, is added to natural gas so leaks can be detected.

Natural gas is shipped hundreds of thousands of miles in underground and above ground pipelines.

Natural gas can be used as a transportation fuel if it is put under pressure and engines are modified.

Petroleum

Description of petroleum:
Petroleum is a liquid hydrocarbon, a fossil fuel formed hundreds of millions of years ago from the remains of tiny sea plants and animals. It can be thin and clear like water or thick and black like tar.

Renewable or nonrenewable:
Nonrenewable

Where petroleum is located and how we recover it:
Petroleum is located underground in rocks in sedimentary basins. Much is under water. We drill wells to find it, then must pump it from the ground.

Ways we turn petroleum into energy we can use:
Petroleum is refined into many different fuels that are burned to produce heat.

Who uses petroleum and for what purposes:
Most petroleum products are used by the transportation sector to move people and goods. Industry burns petroleum to manufacture products and also uses petroleum as a feedstock to produce many products.

Effect of using petroleum on the environment:
Burning petroleum causes air pollution and produces carbon dioxide, a greenhouse gas. Drilling for and transporting petroleum can cause damage to the land and water if there are leaks or spills.

Important facts about petroleum:
We use more petroleum than any other energy source.

The U.S. does not produce enough petroleum to meet our needs.

We import about 48 percent of the petroleum we use from foreign countries.

The Middle East has huge reserves of petroleum.

Petroleum is moved over land mostly by pipeline, and over water by tanker.

Propane

Description of propane:
Propane is a colorless, odorless fossil fuel found with petroleum and natural gas. It was formed hundreds of millions of years ago from the remains of tiny sea plants and animals. It is produced from petroleum and natural gas.

Renewable or nonrenewable:
Nonrenewable

Where propane is located and how we recover it:
Propane is found with petroleum and natural gas deposits and is separated from both fuels during refining and processing.

Ways we turn propane into energy we can use:
We put propane in tanks under pressure to turn it into a liquid so that it is more easily moved from place to place, then we burn it to produce thermal energy.

Who uses propane and for what purposes:
Industry uses propane to make products; farmers use propane for heat in rural areas; homes use propane for outdoor grills; businesses use propane to fuel indoor machinery and as a fleet fuel.

Effect of using propane on the environment:
Propane is a cleaner burning fossil fuel, but burning it does produce some air pollutants and carbon dioxide, a greenhouse gas.

Important facts about propane:
Propane is an LPG—liquefied petroleum gas.

Propane is easily turned into a liquid under pressure. It takes up 270 times less space as a liquid.

Propane is stored in underground caverns and moved by pipelines and trucks.

Propane is called a portable fuel because it is easily transported as a liquid.

Solar

Description of solar energy:
Solar energy is radiant energy from the sun that travels to Earth in electromagnetic waves or rays.

Renewable or nonrenewable:
Renewable

How solar energy is produced:
Solar energy is produced in the sun's core when atoms of hydrogen combine under pressure to produce helium, in a process called fusion. During fusion, radiant energy is emitted.

Ways we turn solar energy into energy we can use:
We can capture solar energy with solar collectors that turn the radiant energy into thermal energy, or with photovoltaic cells that turn radiant energy into electricity. We also use the visible light of solar energy to see.

Who uses solar energy and for what purposes:
We all use the visible light from the sun to see during the day. Many homes and buildings use solar collectors to heat interior spaces and water, and PV cells to produce electricity. Solar power generation facilities use PV cells or mirrors to generate electricity.

Effect of using solar energy on the environment:
Solar energy is very clean energy, producing no air or water pollution.

Important facts about solar energy:
Solar energy is not available all of the time and is spread out so that it is difficult to harness. Today, it is expensive to use solar energy to produce electricity, but new technologies will make solar energy a major energy source in the future.

Uranium (Nuclear)

Description of uranium:
Uranium is a common metallic element found in rocks all over the world.

Renewable or nonrenewable:
Nonrenewable

Where uranium is located and how we recover it:
Uranium is located underground in rock formations. Mines are dug to recover it.

Ways we turn uranium into energy we can use:
Uranium is processed and turned into uranium fuel pellets for nuclear power plants. Uranium atoms are split in the process of fission to produce thermal energy.

Who uses uranium (nuclear energy) and for what purposes:
Nuclear power plants use uranium to produce electricity.

Effect of using uranium (nuclear energy) on the environment:
Uranium fission produces radioactive waste that is dangerous for thousands of years and must be stored carefully. Leaks of radioactive materials pose a danger.

Important facts about uranium (nuclear energy):
Nuclear power plants produce little pollution except for radioactive waste, which must be stored on-site or in special repositories. There is no permanent repository in the United States at this time and most spent fuel is stored on-site at nuclear power plants. A permanent repository is mandated by Congress, but a final location has not been chosen.

Wind

Description of wind energy:
Wind is the circulation of air caused by the uneven heating of Earth's surface.

Renewable or nonrenewable:
Renewable

Where wind energy is located and how we recover it:
Wind is produced when the sun shines on the Earth, heating the land more quickly than the water. The warmer air over land rises and cooler air moves in to take its place, producing convection currents. We can harness wind with sails, mills, turbines, and by living things.

Ways we turn wind into energy we can use:
We use wind turbines that have blades which turn in the wind that turn a turbine to produce electricity.

Who uses wind and for what purposes:
Usually, independent power producers (not big utilities) build wind farms to produce electricity.

Effect of using wind on the environment:
Wind turbines are very clean, producing no air or water pollution. They take up a lot of land, but most of the land can be used for other things, such as farming and grazing cattle, at the same time.

Important facts about wind:
Wind turbines do not produce a lot of electricity, and do not produce it all of the time.

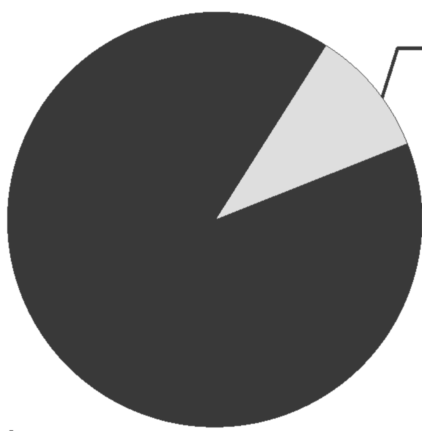
Wind turbines cannot be used in many areas. There must be stable, continuous wind resources.

There are large wind resources on the ocean. The first offshore wind farm in the United States came online in 2016 off the coast of Block Island, Rhode Island.

Renewables and Nonrenewables

Convert the quads into percentages and make a pie chart showing how much U.S. energy in 2015 came from renewable sources and how much came from nonrenewable sources. Round to the nearest hundredth. (Q = quad or quadrillion Btu)

Petroleum*	**35.603 Q = 36.65 %**
Natural Gas*	**28.196 Q = 29.02 %**
Coal	**15.549 Q = 16.00 %**
Uranium	**8.337 Q = 8.58 %**
Biomass	**4.734 Q = 4.87 %**
Hydropower	**2.321 Q = 2.39 %**
Wind	**1.777 Q = 1.83 %**
Geothermal and Solar	**0.638 Q = 0.66 %**
Total Quad BTUs	**97.155 Q = 100.00%**



***Includes Propane**

How We Use Our Energy Sources

In the boxes, describe the main uses of each energy source. Put a * beside the most important use. Some sources may be used in only one or two ways.

	TRANSPORTATION	MAKE PRODUCTS	HEATING/COOLING	LIGHTING	MAKE ELECTRICITY
	turned into ethanol and mixed with gasoline	***burned to make thermal energy to manufacture products***	*burned to heat homes; converted to biogas to heat homes*	*burned to produce light (candles and biogas)*	*burned in waste-to-energy plants to produce electricity*
		burned to make thermal energy to manufacture products	*burned to heat homes*		***burned to make thermal energy to produce electricity***
			used in geothermal exchange systems to heat and cool homes		***thermal energy used to produce electricity***
					kinetic energy used to produce electricity
	used in specially modified vehicles	*** burned to make thermal energy to manufacture products and as a feedstock**	*burned to heat homes and commercial buildings*	*burned in some lanterns and street lights*	***burned to make thermal energy to produce electricity***
	refined into gasoline, jet fuel, diesel fuel	*burned to make thermal energy to manufacture products*	*refined into heating oil and burned to heat homes*	*refined into kerosene and burned in lanterns*	*burned to make thermal energy to produce electricity*
	pressurized for fleet and indoor vehicles	***burned to make thermal energy to manufacture products***	*pressurized and burned to heat homes, barns, and buildings*	*pressurized and burned in lanterns*	
			used to heat homes and buildings	*provides daylighting*	***converted into electricty with PV cells***
U235					***fissioned to make thermal energy to produce electricity***
					kinetic energy turned into electricty

Unit 2, Activity 2: Making a Wind Turbine

Building Your Own Wind Turbine
Lesson by Katie Halpin

Objectives:

1. Students will discover how turning the blades on a turbine can convert kinetic energy into mechanical energy to power a generator that makes electricity
2. Students will be able to make a judgement about design decisions (how many blades, how big the blades are, etc.) to generate maximum current for a sustained period of time
3. Students will interact with the design process in order to plan, develop, build, test, and improve their own wind turbine designs
4. Students will collect and evaluate data to determine the ideal wind turbine design
5. Students will be able to use the wind power equation and the voltage and current to calculate the Watts of power generated from a turbine

Materials:

1. Wind turbine construction materials*
2. A small DC motor for each student/group
3. A large box fan (as a wind source)
4. Multimeter (to measure voltage and current output from the turbines)
5. Student worksheets
6. A 4-function calculator for each student

*Students can either design and create their own turbines from classroom materials (popsicle sticks, straws, construction paper, glue, bits of plastic, etc.), or both Vernier and The NEED Project sell wind turbine kits which can be used to make mini turbines.

Introduction:

- Introduce your students to wind power. Using wind turbines to generate electricity by capturing the kinetic energy from wind is an increasingly common and low-cost renewable energy alternative.
- Indiana has an installed capacity of 2,117 MW, which means that under ideal conditions when all turbines are in use, this is theoretically how much electricity all of the wind turbines in the state can produce. Wind power provides almost 5 percent of the Indiana's total electricity generation.

Activity – Designing a Wind Turbine:

- Students will work through the design process to make their own turbine using the following worksheet. They can either work independently or in small collaborative learning groups (recommended).
- Students will also use the wind power equation to calculate the power in Watts that a turbine can generate.

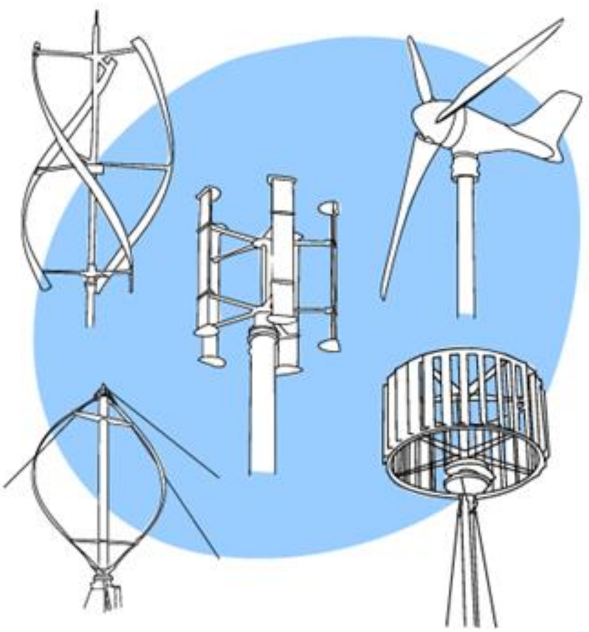
- *Teacher note: As the students are thinking and deciding what should be included in their initial design, walk around to the different groups and ask probing questions about their designs – why they have chosen a certain design, what considerations are they thinking about, have they gotten inspiration from a particular source (i.e. a picture from above, an online search, etc.). It may be worth having a conversation about design considerations prior to beginning the building/designing process. In particular, why are these considerations important? How can these designs be translated to the real world? Go through and list design considerations that they should be thinking about.*
- While the students are building their turbines, monitor for safety, but also be sure to ask the students questions about how they are building their turbines, why they have chosen certain materials, and how they will connect the blades to the nacelle and motor.
- Once students have built their turbines, use the fan to generate wind to turn them. Connect the multimeter to the motor and measure both voltage (volts) and current (amps). Then, have students calculate the wattage by multiplying volts and amps (Power = Voltage*Current)

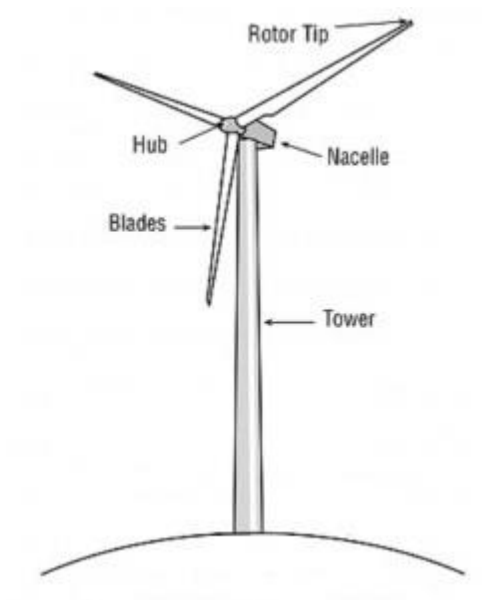
Wrap-Up and Assessment:

- Be sure to check over the questions in the student handout to make sure students can calculate power from measures of voltage and current as well as with wind data using the wind power equation.
- As a class, go over post-design questions to ensure students understand how electricity is generated from turbines and what factors are important to consider (smooth, continuous current, larger turbine blades produce more power, etc.).
- The whole class can also verbally compare the various turbine designs side-by-side in order to assess student understanding of the significance of the turbine blades, number of blades, material used to create the blades, and the balance of the turbine in general.
- Students can also make a private judgement about which design is most effective in the form of a written reflection. This judgement will be important for determining whether students have come to correct assumptions about how the turbine works.
- Ask the student to connect this back to their own personal energy use. Could they power all (or any) of their devices with their turbines? How many or how big would their turbines have to be to charge their cell phones?
- To connect this activity to the following activity (a field trip to a wind farm), students can complete a short reading on wind turbines for homework (following). This reading covers the basic design of a turbine, issues of siting, and briefly touches on public acceptance.

Student Worksheet – Designing a Wind Turbine

There are many different types of wind turbines, each with different strengths and limitations for capturing the wind's energy. Below are some examples of utility-scale wind turbine designs:





The first step in the design process is to create your design. Start by looking at the pictures of turbines above and discuss with a partner how you would design your turbine if you were in charge. Would you design a similar turbine to what you have seen? Do you have another idea for capturing the wind? Perhaps a combination of multiple designs would work best.

Sketch your initial design the box below.

Keep a running list of design decisions that must be considered when designing a wind turbine (ex. Strength and ability to endure strong wind, size and angle of the blades, balance of the turbine etc.) in the space below:

Once you have your turbine design, you may use the provided materials to build your turbine.

Record the maximum voltage and current achieved by your turbine design: ________________________

How does this compare to the maximum voltage and current achieved by all of the designs tested?

Power Equation Data

Wind Power equation: $P = 0.5\rho A V^3$

Where:

P = power output (Watts = kg m^2 s^{-3})

ρ = air density (kg m^{-3}) – *generally a constant = 1.225 kg* m^{-3}

A = area swept by turbine blades ($A = \pi * r^2$) (m^2)

V = wind speed (m s^{-1})

1. Calculate the power output given a wind speed of 4 m/s and an area swept by blades of 100 m^2.

2. The wind has picked up, and now wind speed is 6 m/s. Calculate the new power output given the same turbine.

3. Now calculate the power of a turbine with a turbine area of 150 m^2 with wind speeds of both 4 m/s and 6 m/s.

Given these calculations, which design consideration is most important in building a new turbine to maximize power output?

What would you like to change about your design to get more power?

Sketch your final design the box below. Include a description of materials, including measurements.

Record the maximum voltage and current achieved by your turbine design: ________________________

How does this compare to the maximum voltage and current achieved by all turbine designs?

Post-Design Questions

1. Which turbine do you think would be better for generating electricity, a turbine that has a lowered but sustained current output, or a turbine with a high current achieved but only in small fits or jumps?   Why?

2. Which turbine design generated a constant (or close to constant) electrical current for an extended period of time?

3. What are the design features that you think contributed to this successful design? Use the data you recorded above to support your answer.

4. Use the power equation given below to calculate how many watts of power your turbine design generated.

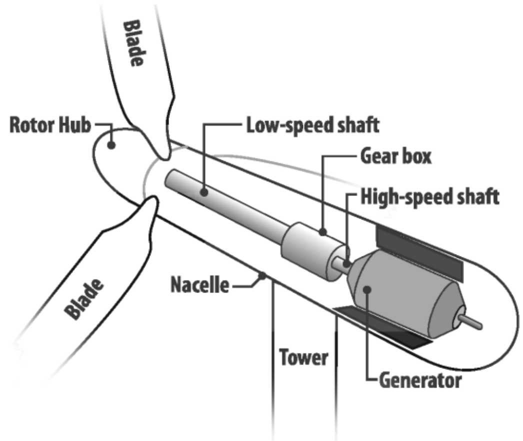
   Power (Watts) = Current (amps)*Voltage (volts)

5. How many watts did the turbine with the highest current generate? Is this enough to charge your cell phone?

6. There are several different technologies that use the same basic mechanism for converting kinetic energy into electricity. Pick one of these technologies and describe how it works. What other design considerations would you have to think about for this technology?

Wind Turbine Reading (from The NEED Project):

Wind Turbine Diagram



▪ Modern Wind Turbines

Today, wind is harnessed and converted into electricity using machines called wind turbines. The amount of electricity that a turbine produces depends on its size and the speed of the wind. Most large wind turbines have the same basic parts: **blades**, a **tower**, and a **gear box**. These parts work together to convert the wind's kinetic (motion) energy into **mechanical energy** that generates electricity.

How a turbine works:

1. The moving air pushes the blades and spins the **rotor**.

2. The rotor is connected to a **low-speed shaft**. When the rotor spins, the shaft turns.

3. The low-speed shaft is connected to one end of a gear box. Inside the gear box, a large slow-moving gear turns a small gear quickly.

4. The small gear turns another shaft at high speed.

5. The **high-speed shaft** comes out of the other end of the gear box and is connected to a **generator**. As the high-speed shaft turns the generator, it produces electricity. This electricity has variable voltage and current.

6. The electric current is sent through cables down the turbine tower to a **transformer** that converts the electricity into a fixed voltage that can safely be sent out on **transmission lines**.

There are many different types of wind turbines with different tower and hub heights, as well as varying blade designs and lengths. Wind turbines can be designed to optimize output for specific ranges of wind speed. Large turbines typically can generate electricity when winds are between 7 and 55 mph (3-25 m/s). Below 7 mph (3 m/s), there is not enough energy in the wind to generate electricity. As the wind speed increases from 7-30 mph (3-13 m/s), the wind turbine generates more electricity. They operate most efficiently, however, when wind speeds fall between 18-31 mph (8-14 m/s). Most large wind turbines produce at their rated power when wind speeds are between 22-55 mph (11-25 m/s), though the wind is rarely this fast, except in extreme storms. When wind speed rises over 55 mph (25 m/s), the wind is so strong, it can damage the turbine. Turbines are designed to shut down in high winds.

Wind turbines also come in different sizes, based on the amount of electric power they can generate. Small turbines may produce only enough electricity to power a few appliances in one home. Large turbines are often called utility-scale because they generate enough power for utilities, or electric companies, to sell. Most utility-scale turbines installed in the U.S. produce one to three **megawatts** (MW) of electricity, enough to power 300 to 900 homes. Large turbines are grouped together into wind farms, which provide large amounts of power to the electric grid.

What a Drag—Aerodynamics

Efficient blades are a key part of generating power from a wind turbine. The blades are turned by the wind and spin the motor drive shaft while, at the same time, they experience drag. This mechanical force slows down the whole system, reducing the amount of power that is generated.

Drag is defined as the force on an object that resists its motion through a fluid. When the fluid is a gas such as air, the force is called **aerodynamic** drag, or air resistance. Aerodynamic drag is important when objects move rapidly through the air, such as the spinning blades on a wind turbine. Wind turbine engineers who design rotor blades are concerned with aerodynamic drag. Blades need fast **tip speeds** to work efficiently. Therefore, it is critical that the rotor blades have low aerodynamic drag.

There are many ways to reduce drag on wind turbine blades:

- Change the **pitch**: the angle of the blades dramatically affects the amount of drag.
- Use fewer blades: each additional blade increases drag.
- Use light-weight materials: reduce the mass of the blades by using less material or lighter material.
- Use smooth surfaces: rough surfaces, especially on the edges, can increase drag.
- Optimize blade shape: the tip of a blade moves faster than the base; wide, heavy tips increase drag.

Gearing Up For More Power

Another key part of generating power in a large wind turbine is the gears. Power output is directly related to the speed of the spinning drive shaft (revolutions per minute or rpms) and how forcefully it turns, or the **torque**.

A large wind turbine has a rotor with blades, a gear box, and a generator. As the blades spin, the rotor rotates slowly with heavy torque. The generator has to spin much faster to generate power, but it cannot use all the turning force, or torque, that is on the main shaft. This is why a large wind turbine has a gear box.

Inside the gear box, there is at least one pair of gears, one large and one small. The large gear, attached to the main shaft, rotates at about 20 rpm with a lot of torque. This large gear spins a smaller gear, with less torque, at about 1,500 rpm. The small gear is attached to a small shaft that spins the generator at high speed, generating power. The relationship between the large and small gears is called the **gear ratio**. The gear ratio between a 1,500 rpm gear and a 20 rpm gear is 75:1. Some small residential wind turbines spin much faster and do not have gears.

Wind Turbine Efficiency—Betz Limit

Wind turbines must convert as much of the available wind energy into electricity as possible to be efficient and economical. As turbines capture energy from the wind, the resultant wind has less energy and moves more slowly. If the blades were 100 percent efficient, they would extract all of the wind's energy and the wind would be stopped. The maximum theoretical percentage of wind that can be captured has been calculated to be about 59 percent by Albert Betz, a German physicist. This value is called the **Betz Limit** and modern turbines are designed to approach that efficiency. Most turbines today reach efficiencies of 25-45 percent.

Wind Farms

Wind power plants, or **wind farms**, are clusters of wind turbines used to generate large amounts of electricity. A wind farm usually has several or dozens of turbines spread over a large area.

Choosing the location of a wind farm is known as **siting** a wind farm. There are many factors to consider – among them are wind speed, available land (or people willing to lease their land), roughness of the terrain, distance to transmission lines, environmental concerns, distance to towns or residential areas, endangered species, etc. A wind developer will work to optimize a wind farm for energy production while weighing all of the relevant factors.

The wind speed and direction must be studied to determine where to put the turbines. The site must have reasonably strong, steady winds. Scientists measure the winds in an area for several years to determine the best sites to optimally lay out a wind farm. As a general rule, wind speed increases with height in most locations, but taller towers cost more. Wind developers try to optimize the turbine height balanced with other factors to maximize energy production.

Turbines are usually built in rows facing into the prevailing wind. The turbines have internal controls to rotate (**yaw**) so they are always facing into the wind. Placing turbines too far apart wastes space. If turbines are too close together, they block each other's wind. Developers optimize the turbine spacing based on the wind speed and direction characteristics to maximize energy production.

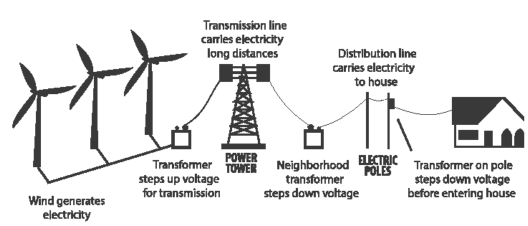
The best sites for wind farms are on ridges, on the open plains, through mountain passes, and near the coasts of oceans or large lakes. Texas, the number one producer of wind electricity in the U.S., has plentiful open space with steady winds, relatively easy permitting requirements, and good transmission from the windy areas in the north and west to the cities in central and southeastern Texas.

Offshore Wind Farms

Because cool air from the water is always moving inland to take the place of warm air that has risen, the wind blows stronger and steadier over water than over land. There are no obstacles on the water to block the wind. There is a lot of wind energy available **offshore**.

Offshore wind farms are built in the shallow waters off the coast of major lakes and oceans. Offshore turbines produce more electricity than turbines on land, but they cost more to build, operate, and maintain. Some challenges for offshore wind farms include the costs and difficulties involved with water-based construction and the impact of salt water corrosion on the maintenance of parts.

Transporting Wind Electricity



WIND FARM

Europe is currently leading the offshore wind industry with over 90% of global offshore wind installation. The United Kingdom, Denmark, China, Belgium, Sweden, Finland, Germany, the Netherlands, Norway, Japan, and Ireland all have offshore wind turbines.

The first offshore wind farm in the United States, the Deepwater Wind project, southeast of Block Island in Rhode Island, began construction in 2015 and was completed in 2016. The five turbine, 30-megawatt wind farm came online late in 2016, and has the ability to power roughly 17,000 homes per year, reducing the reliance on diesel-fired electricity generation and improving air quality for residents.

The Cape Wind project on Nantucket Sound, off the coast of Massachusetts, is another offshore wind project in the works for the U.S. The Cape Wind project was proposed to consist of 130 wind turbines with a capacity to produce 420 MW of electricity. The project, however, has stalled after a decade of legal and logistical concerns. Cape Wind still controls the leased area, but is required by the U.S. Courts to undergo further study of the offshore area before allowing construction to begin.

BLOCK ISLAND WIND FARM, RHODE ISLAND

Image courtesy of Deepwater Wind

Energy on Public Lands

Finding open lands for wind farms is important for the future of wind energy. The Bureau of Land Management (BLM) controls many of the lands with the best wind potential. About 917 megawatts of installed wind capacity in the U.S. is on public lands. BLM works with companies to find sites for wind farms and ensure the turbines do not disturb the land, wildlife, or people. Once wind turbines are installed, and the companies are generating electricity, BLM collects royalties on the electricity sales.

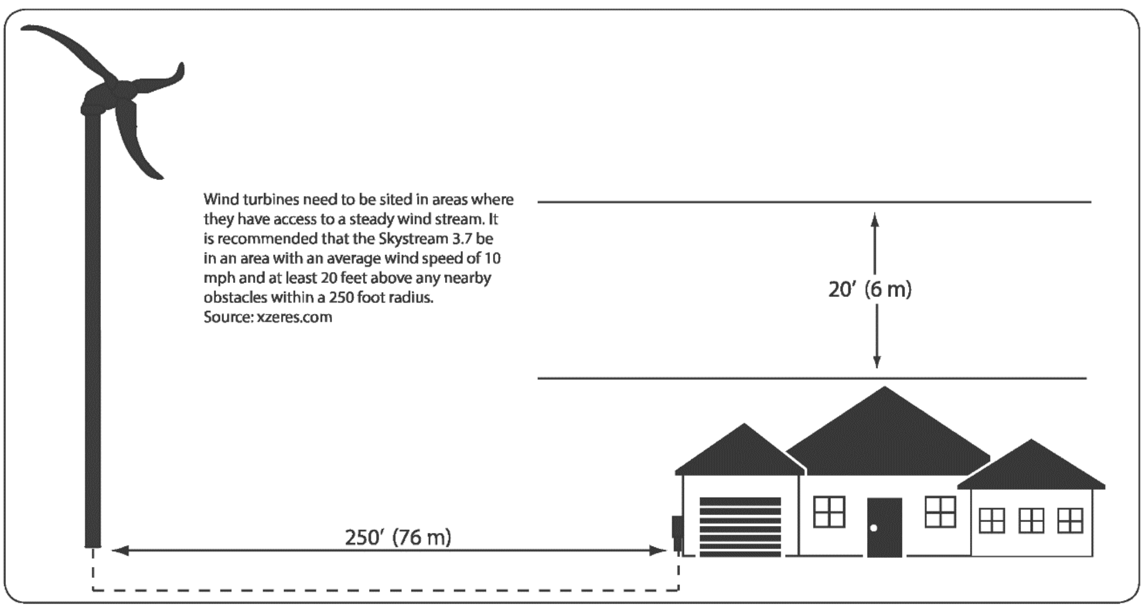
Wind farm developers pay farmers and ranchers for the wind rights on their land. Wind turbines do not interfere with farming or ranching. Crops will grow around the turbines; cattle and sheep can graze under the turbines. Farmers and ranchers receive a share of the wind farm's earnings as extra income.

Texas generates the most electricity from wind energy in the United States, followed by Iowa and Oklahoma. Combined, these three states produce over 40 percent of the nation's total wind-generated electricity.

Small Wind Systems

Wind turbines are not only on wind farms or offshore, they can also be found on the property of private residences, small businesses, and schools. A typical home uses approximately 900 kilowatt-hours (kWh) of electricity each month. Many people are choosing to install small wind turbines to lower or eliminate their electricity bills.

Siting a small wind turbine is similar to siting large turbines, though financial resources required to investigate are much smaller. Potential small wind turbine users typically rely on available wind data and maps. They should try to make sure to minimize



obstructions in the direction of the prevailing wind to maximize energy production. The tip of the turbine blades should be at least 9 meters (30 feet) higher than the tallest wind obstacle. Sometimes this can be a challenge for installing a residential wind turbine if local zoning laws have height limitations. The turbine also requires open land between the turbine and the highest obstacle. Depending on the size of the turbine this may require a 70-150 meter (250–500 foot) radius. Specific siting recommendations can be obtained from the turbine manufacturer.

The Emergency Economic Stabilization Act of 2008 created energy tax incentives to encourage large and small companies, along with individuals, to make energy improvements and invest in renewable energy. Some states and utilities offer additional incentives to residents that install renewable energy systems.

Opportunities and Challenges

Wind is renewable and is a clean source of energy, causing no air or water pollution. Wind is free and an economical energy source for producing electricity. It has the potential to produce up to 20 percent of U.S. electricity demand.

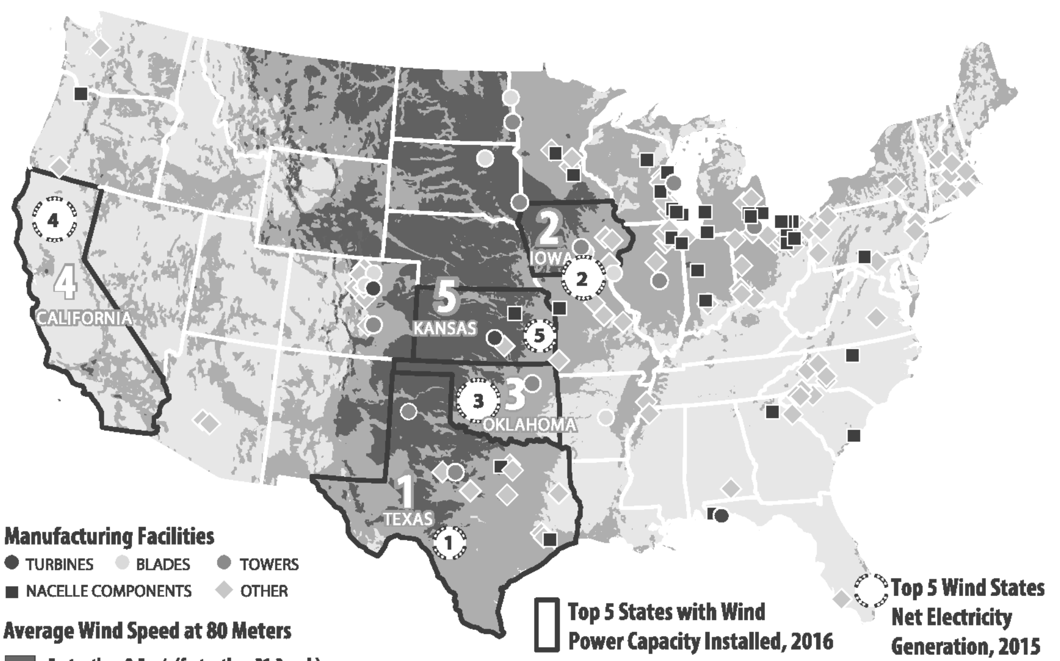
Wind turbines are most effective in areas with consistent wind patterns. While this used to be a limitation, weather data and monitoring and increased technology have allowed for wind turbines to be functional in many types of areas.

There is also concern that wind turbines can harm birds and bats. The wind industry has greatly increased the extent of its environmental monitoring at wind farms before construction and during operation. Wind farm operators can halt or slow operations during certain times of the year or weather events to minimize impacts on migrating birds or endangered species.

Wind turbines can affect the view of the landscape. Some people like the large, modern turbines with their graceful rotation (~12-20 rpm); others prefer the landscape only have trees, mountains, and valleys.

Where the Wind Blows, the Jobs Go

About 50 percent of the parts used to manufacture U.S. wind turbines are produced domestically. Take a look at where the wind blows the strongest and where current manufacturing facilities are located. Also, take note of the top 5 states for wind installation, and the top 5 states for wind generation. What trends do you see?



Manufacturing Facilities

- TURBINES
- BLADES
- TOWERS
- NACELLE COMPONENTS
- OTHER

Average Wind Speed at 80 Meters

- Faster than 9.5 m/s (faster than 21.3 mph)
- 7.6 to 9.4 m/s (17 to 21.2 mph)
- 5.6 to 7.5 m/s (12.5 to 16.9 mph)
- 0 to 5.5 m/s (0 to 12.4 mph)

Data: AWEA, NREL
Note: Does not include potential offshore wind resources.

Top 5 States with Wind Power Capacity Installed, 2016

1.	Texas	20,320 MW
2.	Iowa	6,911 MW
3.	Oklahoma	6,645 MW
4.	California	5,656MW
5.	Kansas	4,451 MW

Top 5 Wind States Net Electricity Generation, 2015

1. Texas
2. Iowa
3. Oklahoma
4. California
5. Kansas

Unit 2, Activity 3: Case Study: Wind Farm in Indiana

Energy Source Case Study: Field Trip to a Wind Farm
Lesson by Katie Halpin and The NEED Project.

Objectives:

1. Students will be able to make a judgement about the intrusiveness of wind farms in Indiana
2. Students will be able to explain issues associated with siting and building a wind turbine including wind energy potential, technical requirements, and sociopolitical factors
3. Students will be able to form an argument about the relative advantages and disadvantages of wind energy in a community

Materials:

1. Pre-arranged appointment to visit one of the wind farms in Indiana
2. Bus/vehicle to transport students
3. Computers with internet access for each student
4. The wind turbine reading assigned for homework after the last activity
5. Whiteboards and whiteboard markers for student groups (optional)

Introduction – Preparing for the Field Trip:

- Go over the brief reading that the students had for homework. Make sure the students understand:
    1. Wind turbines convert the wind's kinetic energy into mechanical energy that generates electricity
    2. According to the reading, turbines operate most efficiently between wind speeds of 8-14 m/s. Look at the Indiana wind resources map (following). Where is the best place to site turbines?
    3. There are various factors that impact how much electricity can be generated including wind speed and turbine design (less blades, light-weight material, blade shape and smoothness, angle of the blades, etc.)
    4. Siting of turbines has many variables to consider – steady wind stream, far enough apart from other things to get a steady wind but close to transmission lines, available land, environmental impacts (especially endangered species, birds, and bats), terrain, and public acceptance (noisy, eye sore, etc.)
- If time allows, have the students do an Internet search about public acceptance of wind turbines. What types of information and arguments do they find? What are the big issues and complaints? Do the students agree with these issues? Is wind energy still a viable option for generating electricity and moving the country towards decarbonization?

Activity – Field Trip to a Wind Farm:

- A tour of a wind farm can be set up by contacting the county's economic development offices. Use the contact information below to find the wind farm nearest to you:
    - Meadow Lake Wind Farm (White County): 574-583-6557
    - Fowler Ridge Wind Farm (Benton County): 765-884-2080

- Headwaters Wind Farm (Randolph County): 765-584-2790

- Before the field trip, have students write down some questions that they would like to ask on the field trip. Encourage students to focus on questions about siting, public acceptance, environmental issues, and how much energy is generated from that wind farm (you can put this generation capacity in context by comparing it to other energy generation sources in your area, i.e. you can look up the capacity of the closest coal plant, natural gas plant, etc. For example, the solar installation at the Indianapolis airport creates 17.5 MW of electricity, and the Eagle Valley coal-fired plant in Martinsville, IN has a nameplate capacity of 302 MW).

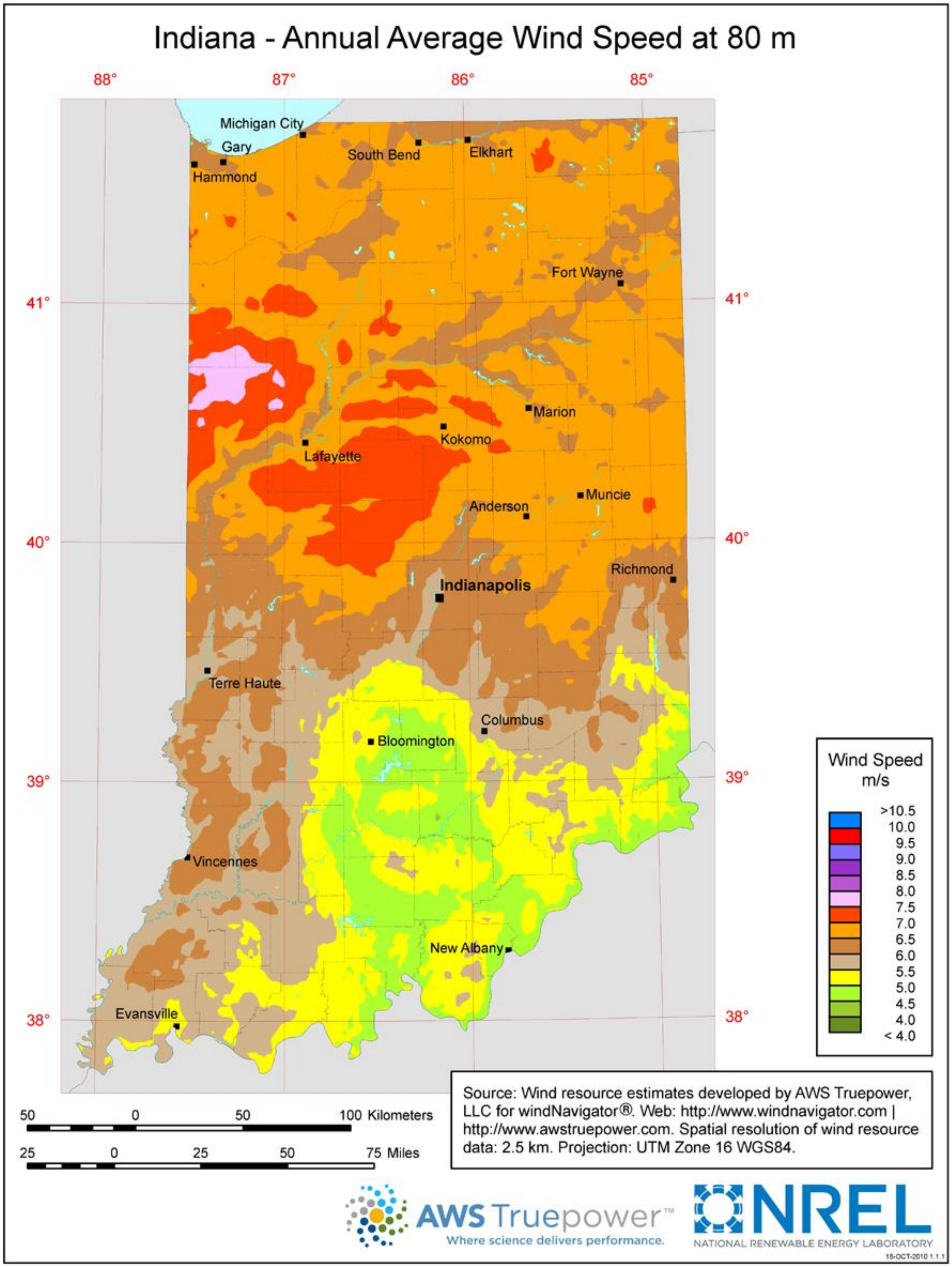
Discussion – Reflections on the Field Trip:

- After the field trip, have students write a reflection (perhaps for homework) about the field trip. Have the students focus on what they learned, what was surprising, and whether they would consider voting to install a wind farm in their town (why or why not?).
- Ask the students to share out their reflections in class if they feel comfortable. This share-out can also take place in smaller learning groups.

Wrap-Up and Assessment – Wind in My Backyard:

- To wrap-up and assess the field trip, have students think about whether they would support a wind farm development near their home or school. Have students get into partners or small groups to discuss:
    - What information they would need to know to make an informed decision?
    - Where would they find the information they need?
    - What would be some of the impacts of a wind farm in the community? How would it effect the larger energy system in Indiana?
    - What are the issues with siting a turbine in their community, who are the stakeholders?
    - What would be the conditions that would have to be true for them to accept the building of a wind farm in their community (i.e. they will only support a wind farming being met if…)
- After the students have come up with answers to the above, have them share with the rest of the class what they have decided (what information they would need, where they would find that information, what are the issues, and what would have to be true in order for them to accept a wind farm development project in their community). They students may use whiteboards to brainstorm and write down what they have decided if they want.
  **Note: If the students decide under no conditions would they ever support wind development in their area, that is fine, but make sure they explain why they do not support wind development.*

Map from the WINDExchange (US Department of Energy):



Unit 2, Activity 4: Energy Systems

Understanding the Energy System

Lesson by Katie Halpin, [The NEED Project](), [Union of Concerned Scientists](), and [the CLEAN Project]()

Objectives:

1. Students will be able to recognize that various generators supply electricity to utilities to meet energy demand at any given time
2. Students will be able to articulate how electricity is distributed from generation facilities into their homes
3. Students will be familiar with some of the issues of meeting electricity demand with renewable energy
4. Students will become familiar with what an energy bill looks like and what information is contained therein
5. Students will be able to discuss barriers to renewable energy uptake from the electricity consumer perspective

Materials:

1. Computers for each student with internet access and a graphing program such as Excel
2. "Energy Economics" Game handouts
3. Sample electric bills
4. From Grid to Home student handout

Introduction & Discussion– Energy Markets:

- To introduce how the energy generation system works, play the "Energy Economics" game provided (following).
- After the game, discuss what students learned from the game. Be sure to clarify that in reality, our electricity is supplied by many different generation facilities selling their energy to several different utilities in almost real-time (and there are different markets to sell electricity on different time frames).
- Have students think about barriers to meet energy demand that renewable energy facilities may have to encounter (ex. Intermittency, transmission loss)
- In light of global climate change, how can we incorporate alternative energy technologies despite some of their drawbacks? Which sources would be good for providing baseload power? What about peak demand? (nuclear and hydroelectric are good for baseload, perhaps wind would be good for peak demand)
- Show students the following curve displaying typical energy demand throughout the day (note the large units on the y-axis, perhaps a discussion about orders of magnitude could be appropriate here. Though the demand changes seem small, they are actually huge).
- Next, discuss the issue of the "solar duck curve" and how utilization of solar power to meet a large proportion of demand poses new challenges for energy suppliers (the afternoon "ramp up" of other electricity sources as the sun becomes less strong).

- Have the students think back to their own energy use and habits from unit 1. How can they change their behaviors to “smooth” out their own personal demand curves? Would this matter or be effective in the grand scheme of energy demand? What if the whole class or school did it?
- Contrast [centralized electricity generation]() (which is what we have currently) with [distributed generation]() (lots of smaller, distributed generation sources). What would we need to do in the US to move from centralized to distributed electricity? How would this help integrate renewable energy and mitigate climate change?

Electricity Demand Curve:

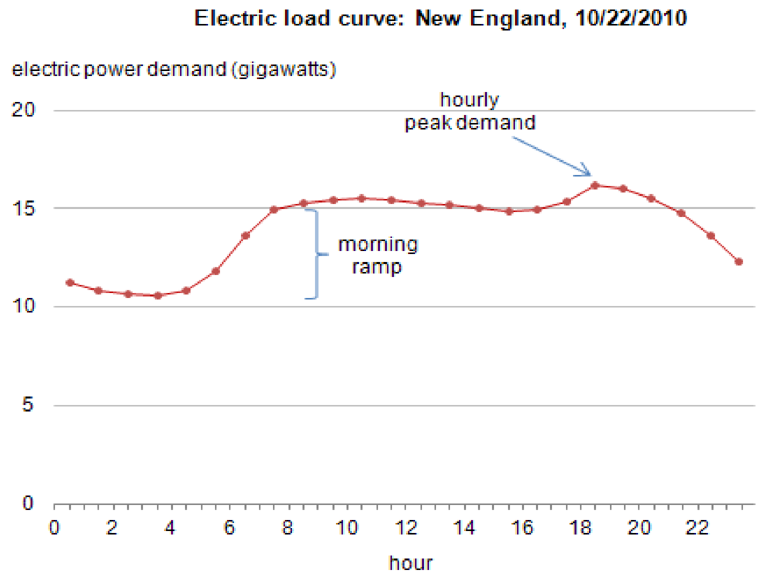


Figure from: https://www.eia.gov/todayinenergy/detail.php?id=830

Solar “Duck” Curve:

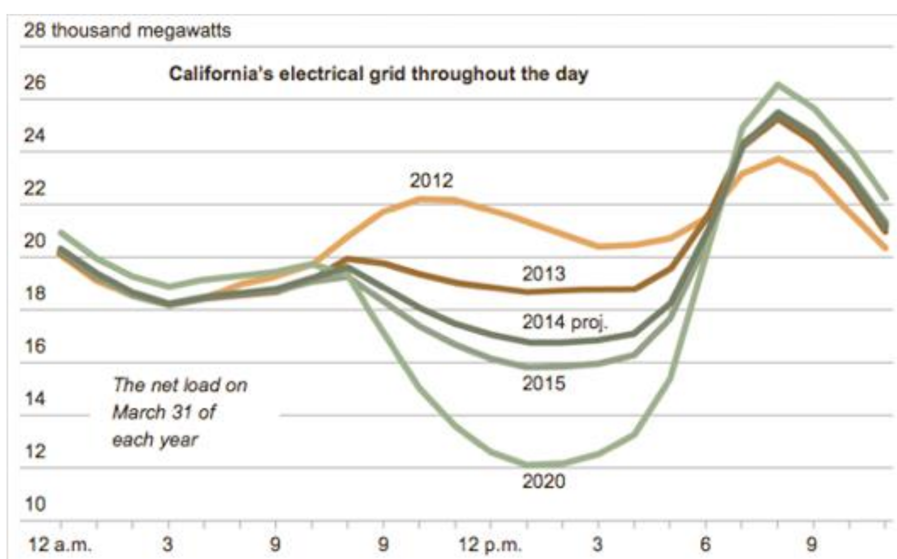


Figure from lecture by Sanya Carley, School of Public & Environmental Affairs, Indiana University

- You can also show students a short YouTube video about how electricity is distributed from the generation source to homes. The first video below is an overview, and then introduces smart grids. The second video describes the energy losses that occur during generation, distribution, and transmission.
  Video about distribution & transmission with smart grids: https://youtu.be/nbPmsBmo03Y
  Video about distribution & transmission with energy losses: https://youtu.be/PNh6PO3aM4s
- Finally, define Renewable Portfolio Standards (Indiana has a voluntary renewable energy target, but Illinois has a full RPS that can be used as an example) and have students think about the advantages and disadvantages of this type of policy requiring states to generate some portion of their electricity from renewables.

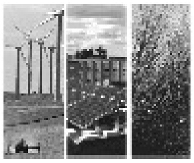
Activity – Examining Electricity Bills:

- Ahead of time, ask students to bring in an example of their family's electricity bill (if possible). Have them redact their addresses and any billing information before bringing the bills in
- Provide extra examples of electricity bills from your home, the school, or the sample bills provided here (following).
- Pass around these example energy bills and have students read and interpret them. Ask the students to identify:
    - The cost of electricity per kilowatt hour
    - The total amount of electricity used that month
    - If applicable, how electricity usage changes month by month
- Next, use the "From Grid to Home" data and worksheet (following) to compare electricity bill averages and to determine the amount of carbon dioxide emitted by using electricity.
- After figuring out how much carbon dioxide they emit given their family's electricity use and the renewable/nonrenewable fuel mix for the region, have the students go to the utility website and see if they can find out how to sign up for green energy programs to help offset carbon dioxide emissions.
    - How easy is it to find information about green energy?
    - How many people do you think go through this process of signing up for green energy?
    - What can utility companies do to make this option more attractive?
    - What are some reasons why consumers might not want to pay more for green energy?
    - Should utility companies be responsible for providing a low-emissions or "green" option for their consumers? Why or why not?
    - What is an alternative way for consumers to push for decarbonization of our electricity system?

Wrap-Up and Assessment:

- Use questioning or exit slips to make sure students understand that energy is supplied by multiple generation sources that sell electricity to utility companies, how electricity is then distributed to homes, and what some of the issues are with renewable energy sources meeting electricity demand. Students should also be able to articulate some of the barriers as a customer to be able to pay for/use low-carbon energy.

Energy Economics Game (from Union of Concerned Scientists):



Playing It Cool: A Renewable Energy Economics Game

This game simulates some of the economic changes necessary to make renewables succeed as large-scale electricity sources. Students buy and sell electricity from various sources—coal, oil, natural gas, nuclear, and renewables—under a variety of economic conditions. By seeing prices rise and fall, students learn about economic barriers and opportunities for renewables.

In the United States today, some renewable sources can generate electricity at a price competitive with fossil fuels, but most utilities do not opt for renewables. Why is this? For the following reasons:

- Oil, coal, and natural gas are cheap and easily accessible (as of 2001).
- Many utilities are unfamiliar with renewable energy technologies, which are generally very different from conventional fossil fuel technologies.
- At the present time, renewables are not appropriate in all areas.
- Environmental costs are not reflected in the economic costs of fossil fuels and nuclear power.
- The fossil fuel and nuclear industries are well established, whereas the renewable industries are still small in comparison. This makes energy from renewables harder to get and, in some cases, more expensive.

Through the game, students should:

1. Observe that the relative price of renewables changes according to environmental regulations, renewables' availability, economic infrastructure, and the prices of fossil fuel and nuclear power.

2. Be able to explain how these economic conditions affect the price of renewables.

3. Understand the concept of a "level playing field." A level playing field is a state of open economic competition where energy sources are subsidized equally and where an energy source's environmental cost is reflected in its price.

GRADES: 8–12

SUBJECTS: social studies, economics, math

TIME: three to five 45-minute class periods

MATERIALS:
- 10 or fewer copies of the game instructions (student handout, pg. 47)
- 10 energy source description cards (pg. 48)
- 10 technology and supply advance cards (pg. 49)
- 5 News Flash pages (pg. 50; you may want to make these into transparencies)
- 10 or fewer copies of utility buyer cards (pg. 53)

Renewables Are Ready Teacher's Guide 43

- 10 copies of energy source selling cards (pg. 54)
- index cards
- tape
- $350 worth of play money for each utility, in $1, $5, $10, $20, and $50 denominations
- $500 extra play money, in small denominations, for teacher

PLAYERS NEEDED: at least 15 students

PREPARATION:

1. Photocopy game instructions, energy source description cards, utility buyer cards, and energy source selling cards.

2. Prepare transparencies of News Flash pages.

3. Prepare approximately $4,000 worth of play money.

Note: *This is a rewarding but complex game, which will work best when students have some knowledge of renewable energy and/or economics, and when there is plenty of time for play and discussion. During the rounds, the "energy marketplace" will be somewhat chaotic.*

PROCEDURE:

1. Tell students they'll be participating in a game about renewable energy called "Playing It Cool."

   a. Clear the center of the room to form a marketplace.
   b. Pick 10 students to be power plants representing different energy sources. Give each a different energy source description card (coal, oil, nuclear, natural gas, solar thermal, photovoltaics, wind, hydropower, biomass, and geothermal), an energy source selling card, and an index card. These students should write the name of their energy source on the index card and tape it to the front of their shirts. This will allow the utilities to identify the energy sources quickly during the game.
   c. Assign the rest of the students to be utilities. If more than 10 students are left, ask some students to team up as one utility. Give each a utility buyer card and $350.
   d. Tell students that you will be the banker for the game.
   e. Distribute copies of the instructions (student handout) to all students.

2. Read the following out loud to the class (or improvise your own material):

   "The year is [current year], the place, the United States. The American economy is sputtering along, using more and more electricity each year.

   [Pointing to students with utility cards] "You people are the utilities, and you provide electricity to American industry and the public. As utilities, you must provide electricity every hour, every day—at the cheapest price you can get it.

   "You can choose to purchase electricity from a variety of energy sources. These people here represent power plants generating electricity using various energy sources [ask them to raise their hands as you read their names]: coal, oil, natural gas, nuclear, solar thermal, photovoltaics, wind, hydropower, biomass, and geothermal. [Ask each energy source to read his or her description card out loud.]

"Your goal—as either a utility or energy source—is to make as much money as you can. As utilities, you buy from the energy sources offering the lowest prices. As energy sources, you offer energy at prices that are high enough for you to make money and low enough that utilities will want to buy energy from you."

3. Go through the specific instructions (student handout) with the students. You may want to read the instructions out loud to the class. You should stress the following points:

   - The goal of the game is to make money.
   - Utilities *must* buy five energy units per round, or be fined. Energy sources do not, however, need to sell all of their units in any given round.
   - Students must keep records of their purchases and sales.

4. Begin the game. Tell students that each round will last five minutes.

   Run through Round 1 as a sample round. Begin by reading News Flash 1, and then read the production costs to the energy sources (or project them on a transparency). Next, pick one technology and supply advance card randomly and read it out loud. Each technology or supply advance changes prices for the duration of the game. Make sure the energy sources write the numbers down. Give the energy sources time to ask each other what prices they plan to set during the round. This will give them a preliminary sense of what price to offer, although they can change it during the round.

   Announce that the marketplace is open. Energy sources may write their selling prices on a piece of paper to hold up for utility buyers.

   When an energy source has sold all of his or her units, he or she should sit down. Similarly, utilities that have purchased their five units of energy for the round should sit down. Announce to the class when one minute is left in the round. Remind utilities that they will be forced to pay a fine if they do not purchase five units of energy.

   When five minutes are up, announce that the energy marketplace is closed. Give students a few minutes to record their sales, purchases, and profits. Collect production costs from the energy sources.

   After the round, review the directions if problems arose. You may want to run this round again, now that students know what to expect.

5. Run Rounds 2, 3, 4, 5, and 6 like Round 1.

   It is possible that some energy sources or utilities may go bankrupt. You may allow them to solicit each other for loans, or simply sit out for the rest of the game.

6. After the final round, discuss the game with the class. Draw a version of the Class Data Sheet (pg. 55) on the blackboard, and get students to fill in the data themselves. After this is done, you may ask students any or all of the following questions:

   General questions:

   a. What did you like or dislike about this game? Was it "fair"?

   b. How do changes in energy prices affect the average American consumer? Ask students to imagine how they would be affected by price changes.

Questions for utilities:

a. From which energy source(s) did you buy the most units throughout the game? What influenced your decision to buy units from these sources?

b. Do you think that cost should be the only factor in determining where utilities buy their electricity?

c. List three or four factors that seemed to influence the price of energy. Did these factors cause the prices to increase or decrease?

d. Were any sources of energy consistently expensive or consistently cheap? Why do you think the game was set up that way?

e. Are environmental costs figured into the cost of energy in this game? Which energy sources would have the highest environmental costs?

f. Do you think that energy prices in the United States are determined by a free, open, competitive market? In your opinion, should the government encourage renewable energy use through subsidies?

Questions for energy sources:

a. Were you able to sell all of your units of energy each round?

b. What change(s) gave you more units to sell (greater availability)?

c. What factor(s) seemed to influence the utilities to buy from you? How did you try to encourage them to do so?

d. Why did you have to pay a production cost at the end of each round? What does this cost represent? Be as specific as possible. (Answers could include cost of machinery, land, labor, etc.)

e. What factors influenced your production costs?

f. Environmentally speaking, how "clean" was your energy? Were the environmental effects of producing electricity from your energy source included in its cost?

g. Do you think that energy prices in the United States are determined by a free, open, competitive market? In your opinion, should the government encourage renewable energy use through subsidies?

7. You may want to end by reviewing some of the material covered.

   One way to wrap up is to have students discuss how this game differs from real life. The following are some of the important points to stress:

   a. Energy conservation is not an option in this game. In general, it is cheaper to use energy more efficiently than it is to purchase or produce additional energy.

   b. Economic change usually occurs slowly. Change does not always happen with sudden "news flashes." Energy source availability, for instance, usually changes gradually, but unexpected international events or environmental disasters can lead to sudden changes.

Playing It Cool: Student Instructions

STUDENT HANDOUT

UTILITIES:

You will start the game with $350.

You must buy five units of energy each round. If the round ends before you have bought your units, you will have to pay the bank a fine equal to the highest price offered for a unit of energy during the round times the number of units you need.

When each round begins, find out what prices different energy sources are offering. Then buy from as many sources as you wish, but *keep the amount you spend as low as you can.*

Write down on your buyer's card which kinds of energy you bought and how much each cost. At the end of each round, write down how much money you spent.

ENERGY SOURCES:

Make as much money as you can each round, by selling energy units to utilities.

At the beginning of each round, you will be given a production cost. This is how much it costs you to produce one unit of electricity from your source. A technology and supply advance card drawn at the beginning of each round could reduce this cost and increase the available amount of your energy source. Make sure that you write down any changes in cost caused by a technology or supply advance for your energy source.

Since your goal is to make as much money as possible, charge utilities the highest price you can for one unit of energy. But remember, you're competing with other energy sources, so if you charge too much, utilities will buy from other sources.

Before or during each round, you can ask other energy sources how much they plan to charge per energy unit. This will give you a sense of how much you should charge. If you need to, change the price you offer during the round to remain competitive.

Keep track of the number of energy units you sold during a round, and the price you charged for each unit. Write this information down on your energy source selling card at the end of the round. Since some energy resources are limited, *you cannot sell more energy then you have available for each round.* Any unsold units remaining at the end of the round are forfeited.

At the end of each round, you must pay the banker your total production cost. This amount is the production cost per energy unit multiplied by the number of units you sold.

Mark down how much money you have left after you pay the banker.

ENERGY SOURCE DESCRIPTION CARDS

Wind

When wind blows on a wind turbine, its blades turn, powering an electricity generator. Electricity from wind is cheap, and it produces no pollutants. Wind turbine "farms" require large amounts of land, though, and only windy areas can generate electricity economically. Currently, wind generates electricity in large-scale wind-farms as well as in small backyard operations.

Geothermal

Geothermal energy is heat energy stored underground in Earth's crust, in water, rock, or magma. Geothermal energy from water reservoirs is cheap, although there are limited areas where it can be tapped. Other types of geothermal energy are under development.

Solar Thermal

In a solar thermal system, mirrors concentrate sunlight on a liquid, heating it into steam. This steam then turns a generator. Solar thermal energy is not yet widespread, and will probably be practical only in sunny regions.

Hydropower

Hydropower is energy from moving water. In a hydroelectric dam, falling water turns a turbine, creating electricity. Hydropower generates about seven percent of U.S. electricity. Most feasible hydropower sites have already been developed, however. Building large new dams floods extensive areas, causing social and environmental disruption.

Nuclear Fission

When unstable, or radioactive, atoms split, they produce large amounts of heat. Nuclear reactors use this heat to create steam, which then powers electricity generators. Nuclear energy is expensive, though, and can be dangerous. Radioactive leaks can pose problems to public health and safety, and the United States currently has no adequate method of disposing of radioactive waste.

Coal

Burning coal produces heat, which can then boil water and drive a steam turbine. Coal is a nonrenewable resource, but the United States has large reserves of it. Although it is one of the cheapest ways of generating electricity, burning coal produces more air pollution than other energy sources and contributes to global warming.

Photovoltaics

A photovoltaic, or solar, cell converts sunlight directly into electricity, without any polluting by-products. Solar cells are practical for applications that are isolated from major power lines, but they are still expensive for utility-scale use. Technical advances and mass production will help bring their price down in the next decade.

Oil

Burning oil is used to drive a combustion turbine, an engine similar to those used in jet planes. Oil is a nonrenewable resource and is relatively cheap at present. Much of our oil is imported from the Middle East, however, so our supply is vulnerable to conflicts in that region. Burning oil produces carbon dioxide, a heat-trapping gas, and other air pollutants.

Natural Gas

Burning natural gas is used to power a combustion turbine, similar to those used in jet planes. Domestic natural gas supplies are more limited than coal, making them vulnerable to sudden price increases as demand rises. Natural gas produces the least carbon dioxide and other air pollutants of any fossil fuel when it is burned.

Biomass

Biomass is plant matter that can be burned to produce heat and electricity or converted to liquid and gaseous fuels. Biomass can be organic material from trash and other wastes, or it can be grown specially for energy use. The price of biomass varies widely depending on its nature. Burning biomass produces carbon dioxide, a heat-trapping gas, but if the land used to grow biomass is replanted, the new plants remove equal amounts of carbon dioxide from the atmosphere, resulting in no net contribution to global warming.

TECHNOLOGY AND SUPPLY ADVANCE CARDS

(Cut these out, mix them up, and pick one at the beginning of each round)

TECHNOLOGY ADVANCE!

Scientists develop new techniques for producing photovoltaic cells, doubling their efficiency and slashing their production cost in half.

- Photovoltaic production costs are $5 less, and 4 additional units are available.

TECHNOLOGY ADVANCE!

Energy engineers perfect the parabolic trough system, a method of solar thermal electricity generation. Now it can produce electricity at lower cost and with increased efficiency.

- Solar thermal production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

Energy engineers develop new techniques for burning coal. Coal-fired power plants will now burn coal more efficiently and produce fewer pollutants. As a result, electricity generation from coal will cost less.

- Coal production costs are $1 less.

SUPPLY ADVANCE!

Extensive new reserves of natural gas have been discovered in the United States.

- Natural gas production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

A new gas-cooled nuclear reactor is developed. This reactor, when standardized and developed across the country, will provide electricity more cheaply and safely than before.

- Nuclear production costs are $2 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

Geological engineers discover how to harness hot dry rock, a form of geothermal energy.

- 10 more units of geothermal energy are available.

TECHNOLOGY ADVANCE!

The ZP5552 model wind turbine, called "the biggest breakthrough in wind technology since the sailboat," has hit the markets. This ultra-efficient, low-cost wind turbine will slash wind-generation prices.

- Wind production costs are $3 less, and 10 more units are available.

SUPPLY ADVANCE!

Opening the Alaska National Wildlife Refuge to oil drilling increases U.S. reserves of oil.

- 1 more unit of oil is available.

TECHNOLOGY ADVANCE!

An efficient technology for converting wood to a combustible gas has been developed. This technology should reduce the cost and increase the availability of biomass energy.

- Biomass production costs are $1 less, and 5 more units are available.

TECHNOLOGY ADVANCE!

New, small-scale hydro technologies are developed, resulting in a decrease in cost and increase in availability.

- Hydropower production costs are $1 less, and 2 more units are available.

ROUND 1

BUSINESS AS USUAL .... Business is proceeding as usual in the U.S. energy industry.

The United States uses fossil fuels such as coal, natural gas, and oil for most of its electricity. Nuclear power provides 21 percent of U.S. electricity. Renewable energy provides only 10 percent, mostly from hydropower.

The U.S. government subsidizes the fossil fuel and nuclear power industries. Neither the utilities nor these industries have to pay fully for environmental problems caused by these energy sources.

By contrast, the renewable energy industry is poorly funded by the government. Renewable energy sources are not as well developed as they could be. However, some renewable sources, though not widely used, are already economically competitive with other sources for generating electricity.

	Production Cost (dollars per unit)	Availability (units per round)		Production Cost (dollars per unit)	Availability (units per round)
Coal	6	50	Solar Thermal	9	1
Oil	8	10	Photovoltaics	25	1
Natural Gas	6	25	Wind	8	1
Nuclear	10	25	Hydropower	6	6
			Biomass	5	2
			Geothermal	5	2

ROUND 2

NEWS FLASH!!! .... AP – Growing concern over global warming has caused Congress to approve a "carbon tax" that will affect all utilities that burn fossil fuels.

When implemented, this tax will require utilities that burn coal, oil, and natural gas to pay a fee for each ton of carbon dioxide they produce.

This tax will make energy from fossil fuels more expensive and will encourage the development of renewable energy technologies.

	Production Cost (dollars per unit)	Availability (units per round)		Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50	Solar Thermal	9	2
Oil	10	10	Photovoltaics	25	2
Natural Gas	7	25	Wind	8	2
Nuclear	10	25	Hydropower	6	7
			Biomass	5	3
			Geothermal	5	3

ROUND 3

NEWS FLASH!!! .... AP – In an unexpected move, Congress removed research and development (R&D) subsidies for the nuclear power industry.

Over the last few decades, the Department of Energy spent a large portion of its R&D budget on nuclear energy. Over the next decade, the nuclear power R&D budget will be reduced by five percent per year, bringing nuclear research in line with research on renewable energy by 2010.

"We felt that federal funding for nuclear power was excessive in light of the nuclear industry's performance over the past 30 years," said Senate leader Neil O'Tip.

Congress also repealed the Price-Anderson Act, which limits a nuclear plant's liability in case of a nuclear accident. Nuclear plant insurance rates will now skyrocket.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	10	10
Natural Gas	7	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	9	3
Photovoltaics	25	3
Wind	8	3
Hydropower	6	7
Biomass	5	4
Geothermal	5	4

ROUND 4

NEWS FLASH!!! .... AP – In what is perceived as a victory for the renewable energy industry, Congress today passed big new tax credits for renewable energy development.

Power producers that build new renewable energy plants instead of fossil fuel or nuclear plants will receive a large tax break. Congress enacted the tax credits to spur the development of clean, sustainable, renewable energy.

As a result of the tax credits, electricity from renewable sources is expected to become much more available. It should also be less expensive.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	10	10
Natural Gas	7	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	15
Photovoltaics	15	10
Wind	5	15
Hydropower	6	8
Biomass	5	10
Geothermal	5	6

ROUND 5

NEWS FLASH!!! .... AP – Cloudy spell in California enters sixth week; confidence in solar energy plummets.

Thirty-six days of clouds, rain, and fog in most of California have caused utilities in that state to reconsider their heavy investments in solar energy. The freak weather has made electricity from California's solar thermal and photovoltaic power plants virtually unavailable, while increasing the demand for electricity as people spend more time indoors.

California utilities took advantage of renewable energy mix credits passed by Congress several years ago and have been buying solar thermal and photovoltaic units as fast as suppliers could provide them. Approximately 10 percent of California's energy is now provided by solar. Unfortunately, this electricity is available only when the sun is shining, as adequate methods of storage have not yet been perfected.

Concern over the reliability of solar energy has caused utilities to cancel orders for new solar thermal and photovoltaic plants. These cancellations are expected to cause bankruptcies and business failures in the relatively young solar industries.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	15	5
Natural Gas	13	25
Nuclear	20	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	7
Photovoltaics	11	5
Wind	5	15
Hydropower	6	9
Biomass	5	10
Geothermal	5	6

ROUND 6

NEWS FLASH!!! .... AP – Iraq invades Kuwait; oil prices soar.

In a sneak attack, Iraqi troops pushed over the border into Kuwait late last night. Tensions between the two countries over oil-production quotas, which led to a similar conflict in 1991, had been mounting over the past year.

Hostilities between the two countries, which could be lengthy, are expected to impede the flow of oil from the Middle East to the United States. In early trading on international markets today, the price of oil was up $10/barrel.

Skyrocketing oil prices are almost certain to mean an increase in the cost of electricity. Although only three percent of the nation's electricity is generated from oil, a rise in oil prices has historically produced a parallel rise in the price of natural gas. Oil and gas together account for 19 percent of the nation's electricity production.

	Production Cost (dollars per unit)	Availability (units per round)
Coal	10	50
Oil	15	5
Natural Gas	13	25
Nuclear	13	15

	Production Cost (dollars per unit)	Availability (units per round)
Solar Thermal	6	15
Photovoltaics	11	10
Wind	5	15
Hydropower	6	9
Biomass	5	10
Geothermal	5	6

UTILITY BUYER'S CARD
(Buy 5 units of energy each round)

		KIND OF ENERGY BOUGHT	COST
ROUND 1	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 2	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 3	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 4	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 5	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	
ROUND 6	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL:	

ENERGY SOURCE SELLING CARD

____
(name of your energy source here)

	PRODUCTION COST	AMOUNT AVAILABLE TO SELL	AMOUNT SOLD	AMOUNT TO PAY BANKER (production cost x amount sold)	PROFIT (money left)
ROUND 1					
ROUND 2					
ROUND 3					
ROUND 4					
ROUND 5					
ROUND 6					

CLASS DATA SHEET

ENERGY UNITS PURCHASED
(to be filled in by utilities)

	COAL	OIL	NATURAL GAS	NUCLEAR	SOLAR THERMAL	PHOTOVOLTAICS	WIND	HYDROPOWER	BIOMASS	GEOTHERMAL
ROUND 1										
ROUND 2										
ROUND 3										
ROUND 4										
ROUND 5										
ROUND 6										

ENERGY SOURCE PROFITS
(to be filled in by energy sources)

	COAL	OIL	NATURAL GAS	NUCLEAR	SOLAR THERMAL	PHOTOVOLTAICS	WIND	HYDROPOWER	BIOMASS	GEOTHERMAL
ROUND 1										
ROUND 2										
ROUND 3										
ROUND 4										
ROUND 5										
ROUND 6										

Sample Electricity Bills (from The NEED Project):

Sample School Electric Bill

Nov 27, 2014 1

Customer Bill
ABC Elementary School
Anytown, USA

Your Electric Company

Billing and Payment Summary

Account # 000-1234 2	Due Date: Jan 02,2015 3
Total Amount Due:	$ 7,462.61 4

To avoid a Late Payment Charge of 1.5% please pay by Jan 02, 2015

Previous Amount Due:	$ 8,152.93
Payments as of Nov 27:	$ 8,152.93

Meter and Usage
Current Billing Days: 34

Usage History

Billable Usage

Schedule 130	*10/23 - 11/26* 12	
Total kWh	12192	
Dist Demand	61.0 10	
Demand	57.0	
Schedule 130	*10/23 - 11/26*	
Total kWh	69888	
Dist Demand	272.0 10	
Demand	259.0	

Measured Usage 5

Meter: 000-1234	*10/23 - 11/26*
Current Reading	4147
Previous Reading	4020
Total kWh	12192 6
Current Reading	.60
Demand	57.60 11
Multiplier: 96	
Meter: 111-4567	*10/23 - 11/26*
Current Reading	51746
Previous Reading	51382
Total kWh	69888 6
Current Reading	1.35
Demand	259.20 11
Multiplier: 192	

Explanation of Bill Detail

Your Electric Company	1-800-123-4567
Previous Balance	8,152.93
Payment Received	8,152.93
BALANCE FORWARD	0
Non-Residential Service (Schedule 130)	*10/23 - 11/26*
Distribution Service	
Basic Customer Charge	86.52
Distribution Demand	206.29
13 Electricity Supply Service (ESS)	
ESS Adjustment Charge	83.93 CR
Electricity Supply kWh	214.94
ESS Demand Charge	558.85 7
Fuel Charge	353.81
Sales and Use Surcharge	2.68 8
Non-Residential Service (Schedule 130)	*10/23 - 11/26*
14 Distribution Service	
Basic Customer Charge	86.52
Distribution Demand	919.87
Electricity Supply Service (ESS)	
ESS Adjustment Charge	374.243 CR
Electricity Supply kWh	909.41
ESS Demand Charge	2,539.36 7
Fuel Charge	2,058.15
Sales and Use Surcharge	13.38 8
TOTAL CURRENT CHARGES	7,463.61 9
TOTAL ACCOUNT BALANCE	7,463.61 4

For service emergencies and power outages, call 1-800-123-4567.

Mailed on Nov 28, 2014

Please detach and return this payment coupon with your check made payable to Your Electric Company.

Bill Date Nov 27, 2014 1

Please Pay by 01/02/ 2015 3
$ 7,463.54 4

Payment Coupon

Amount Enclosed

Account # 000-1234 2

Send payment to:

ABC Elementary School
123 Main Street
Anytown, USA 98765

Your Electric Company
PO BOX 123456
Anytown, USA 98765

01166005000 000000009368 6868686 0001234 11272007

24 School Energy Survey

Sample School Natural Gas Bill

ABC Elementary School
Anytown, USA

NOTE: The bill you received on or around Friday, Nov. 2 was calculated using estimated usage instead of the actual meter reading. This invoice reflects your actual meter reading. If your new amount due is more than what was indicated on your previous bill, please remit payment for the difference. If it is less, and you've already paid, the difference will be credited to your account and shown on your next bill. We apologize for the inconvenience.

1 Account Number	2 Billing Date	3 Next Meter Reading	4 Next Billing Date
000-12345678	Nov 15, 2014	Dec 3, 2014	Dec 4, 2014

Visit our web site at www. yourgascompany.com

If you have any questions call 1-800-000-0000

Credits & Charges Since Your Last Bill

Payments Received - Thank You	$1,302.60 CR	5
Outstanding Balance	$0.00	

Current Charges

General Service

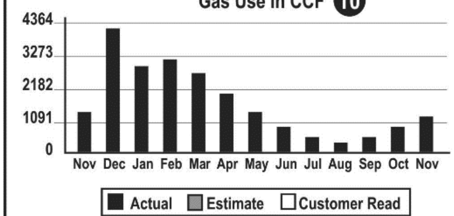
Delivery	6	282.14
Gas Supply	7	1,377.91
Total Current Charges		**$1,660.05**
Total Account Balance	8	**$1,660.05**

For Gas Leaks, call 1-800-123-4567

Monthly Usage Comparison

Heating Degree Days For This Billing Period	2013		2014	NORMAL
	160	9	51	138

Gas Use in CCF 10



Billing Period and Meter Readings

Date	Read Type	Reading
October 30, 2014	Actual	70320
October 01, 2014	Actual	68985

11

CCF used in 29 days: 1335 12
Meter Number 123456 13

Please pay by Dec 10, 2014 , To Avoid A Late Charge of 1.5% Per Month

EnergyShare has helped customers pay heating bills of all kinds. You can help by adding $1, $2, $5, $10, $15, or $20 to your gas bill payment. 14

Please make checks payable to Your Gas Company and return this portion with your payment. Thanks!

YOUR GAS COMPANY
PO Box 123456 Anytown, USA 98765

PREVIOUS BALANCE	$0.00	
Total Current Charges	$1,660.05	Pay By Dec 10, 2014 15
Total Account Balance	$1,660.05	
Account # 000-12345678	Amount Enclosed	16

ABC Elementary School
123 Main Street
Anytown, USA 98765

Your Gas Company
PO BOX 123456
Anytown, USA 98765

0116600500000000000009368686868686000012345678

From Grid to Home Student Worksheet
(Worksheet and data from the CLEAN Project)

Directions: Use the following data in the Excel Spreadsheet to answer the questions below.

From Grid to Home Data:

Region	Avg. Mont	Avg. Mont	Coal (%)	Natural G	Nuclear (%	Hydro (%)	Other Rer	Fuel/Oil (%
New England	649	108	15	41	28	5	6	1
Middle Atlantic	722	101	36	19	35	6	2	2
East North Central	830	81	69	5	23	0.5	1	0.5
West North Central	970	81	74	5	15	2	3	0.5
South Atlantic	1156	116	53	17	24	1	2	3
East South Central	1290	108	64	12	19	3	2	1
West South Central	1149	128	37	46	12	1	4	1
Mountain	908	85	57	25	7	8	2	0.5
Pacific Contiguous	699	83	4	37	12	38	9	1
Pacific Noncontiguou	659	135	12	21	0	8	4	54
US Total	**9032**							
National Average		**102.6**	**42.1**	**22.8**	**17.5**	**7.25**	**3.5**	**6.45**

Questions:

1. Produce a bar chart showing residential electricity use (in kWh) from highest to lowest by region.

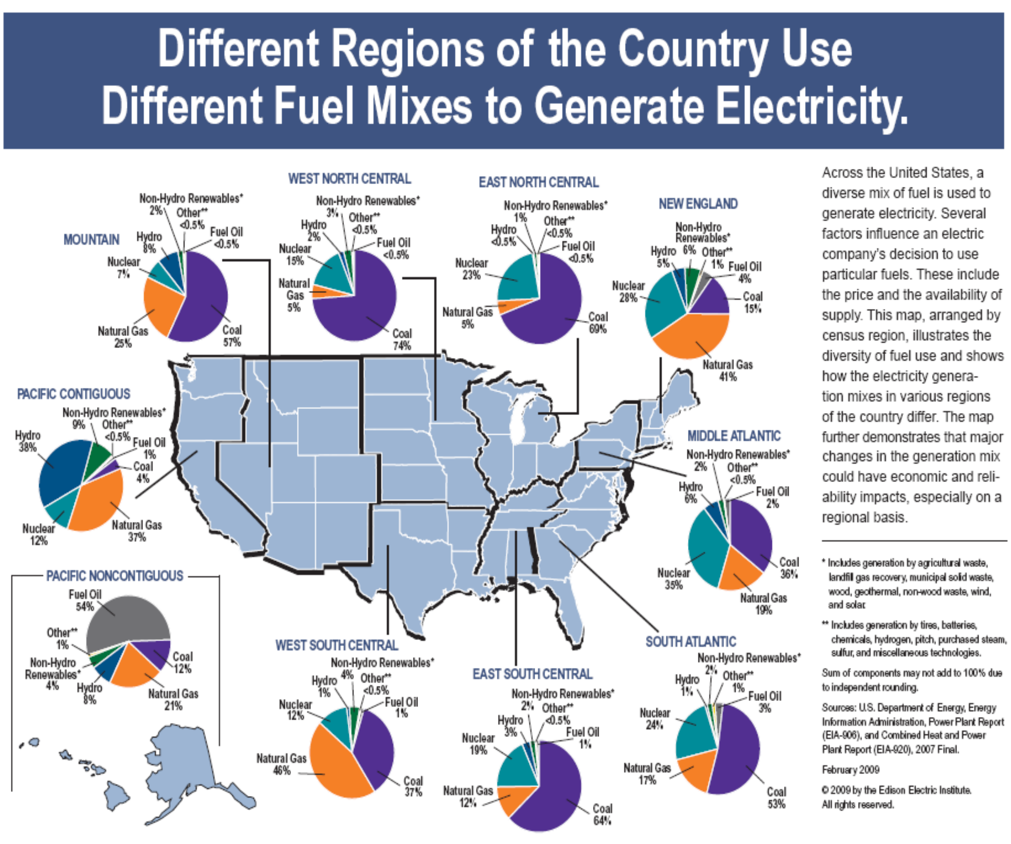
2. Look at your electrical bill for last month. Is your household energy usage above or below your regional average? Discuss why it may be higher or lower.

3. How many kWh of your electricity came from each source? (Assume your household electricity is produced according to the pie chart for your region shown in the figure on the next page).

4. How many tons of carbon dioxide did your house hold produce last month? (See table below.)

Energy Source	Pounds of CO2 produced per kWh electricity
Coal	2.095
Natural Gas	1.321
Petroleum	1.969

6. Calculate how many kWh your household would need to reduce to cut your CO2 emissions by 10%?
How much money would that save your household?



Unit 2 Summative Assessment – Installing Solar Panels

Making Energy Decisions: Would You Install Rooftop Solar?
Lesson by Katie Halpin

Objectives:

1. Students will be able to apply their knowledge of the energy system to assess the relative merits of adopting a renewable energy technology
2. Students will grapple with imperfect information to make a decision about the feasibility of rooftop solar in Indiana
3. Students will address renewable energy uptake from an environmental, economic, and a sociopolitical perspective

Materials:

1. Assessment rubric for each group
2. Enough peer review forms so each student can fill out the peer review for at least 3 other groups
3. Ability to print posters (or recommendation for where students can print posters)
4. Ability to hang posters in the classroom, hallway, or common area of school

Assessment Prompt:

Now that you have become an expert on Indiana's energy system, you have decided to consider whether or not you should install a solar PV installation on the roof of your family's home. In order to make this decision, you and your group need to first outline what information you need to inform your decision and where this information can be found. Then, you will try to find this information and make a decision about whether or not installing these solar panels would be a good idea. You must support your decision with evidence and reasoning, and address any questions or issues you may face if you do choose to install the solar panels. You must also include a calculation of either how many solar panels you would need to install to meet your monthly electricity needs, or alternatively calculate how much of your energy bill would be offset by this installation. You will make a poster (use a template in PowerPoint or Adobe InDesign) to present your decision and evidence supporting this decision. The class will then have a poster session in which students will be able to see each other's posters. You will be required to peer review 3 other poster during this poster session.

**Teaching note: this may be a difficult and frustrating challenge for students because of the open-endedness of this assessment. I would recommend allotting a considerable amount of class time for doing this assessment in-class so you can scaffold and guide the groups as necessary. For group work management, consider using a tool such as a "scrum" to organize the students so they know which tasks they are responsible for doing and what still needs to be done. For information on scrum group work, see:*

Pope-Ruark, R. (2012). We scrum every day: Using scrum project management framework for group projects. *College teaching*, *60*(4), 164-169.

Assessment Rubric:

Criteria	Above Average	Average	Below Average	Incomplete
Decision Made	Decision about installing panels clearly stated and easy to see on poster	Decision about installing panels stated on poster	Decision about installing panels stated but not clear or easy to find on poster	Decision about installing panels not stated on poster
List of information needed and where to find information	Comprehensive list of information compiled with relevant and reliable sources	Satisfactory list of information compiled with reliable sources	Incomplete list of information compiled and/or questionable sources	Either list of information or sources used missing
Evidence to support decision based on environmental, economic, and sociopolitical factors	Outstanding consideration of all factors and excellent reasoning and evidence used to support decision	All factors considered and sound evidence and reasoning used to support decision	One or more factors not considered, and/or weak evidence to support decision	Does not provide evidence to support decision
Calculation about number of solar panels/how much electricity will be offset	Sound, evidence-based assumptions and clear, well-done calculation performed correctly	Calculation done correctly with sound assumptions stated	Calculation is incorrect, incomplete, or assumptions are inappropriate	Calculation not complete and has missing assumptions
Presentation and professionalism of poster	Well-done and professional poster that demonstrates extra effort made, all group members can talk coherently about decision	Clear and professional poster, all group members can answer questions about decision	Poster is lacking, and/or not all group members can answer questions about decision	Very poor and incomplete poster, few group members can answer questions about decision

Comments:

Peer Review Form for Poster Presentations:

1. What was this group's decision and why did they decide this way?

2. What was the most convincing argument the group used to support their decision? What was the least convincing argument the group used?

   Most Convincing:

   Least Convincing:

3. Did the group perform a sound calculation to determine how many panels they would need or how much electricity would be offset? Why or why not?

4. Did this group fail to consider something? If so, what?

5. Question I asked the group about their poster:

Thesis Discussion

Introduction

This discussion's purpose is to explain why the accompanying curriculum guide represents the best lessons to promote energy literacy through teaching high school students about energy behaviors and use. In the first unit, activities are designed to address misconceptions surrounding personal energy use, energy efficiency, and energy conservation. The second unit has students confront misconceptions concerning where our energy comes from, what types of energy sources we use, and what are the basic principles of the energy system economy. These lessons can be utilized on their own, or as a systems thinking curricular unit to address energy topics from the scale of personal energy use up to large-scale energy systems analysis. The activities within the curriculum guide are situated in educational theory as well as current research in energy literacy, which make them effective teaching tools to promote deep learning and will allow students to use the knowledge they have learned in a productive way. This curriculum guide is tied to educational research and theory in that it is place-based and relevant to students' lives, fosters independent thinking that can lead to responsible action, allows students to strengthen their communication skills in order to apply and demonstrate their knowledge, engages students in active and in-depth learning while activating prior knowledge and addressing misconceptions, and incorporates both formative and summative assessment into the learning process (NAAEE, 2015; Smith, 2013; Birmingham & Calabrese Barton, 2013; Broadbent, 2002; National Research Council, 2000). These activities also promote energy literacy because they address the cognitive, affective, and the behavioral domains by showing students how energy relates to their lives, how energy use impacts the environment and society, and why there is a need to promote energy conservation, efficiency, and alternative energy uptake (DeWaters et al., 2007).

The Value of a Systems Thinking Curriculum

The cornerstone of "systems thinking" is to focus on the interactions between the parts of a complex system in order to understand how the system as a whole functions (Institute of Play, 2014; Boersma et al., 2011; Ben-Zvi Assaraf & Orion, 2005). Some of the skills that support systems thinking processes are understanding relationships such as feedback mechanisms, cause and effect, how structure influences behavior, recognizing that models have boundaries, and that systems tend to be nonlinear. Furthermore, students engaged in systems thinking practice scientific reasoning skills such as interpreting qualitative and quantitative data and applying content knowledge of a wide array of different disciplines (Sweeney & Sterman, 2000). By thinking about relationships between elements within a system and the interdependence between various systems, systems thinking approaches can help students think critically to generate solutions to complex problems (Richmond, 1993).

Systems thinking as an important tool for critical thinking has been incorporated into the popular "21st Century Skills," which has promoted systems thinking as a way to solve problems encountered in the modern age (P21, n.d.). The hallmark of a 21st Century problem, for which systems thinking poses an avenue for finding solutions, is a problem that is complex, interdisciplinary, involves judgement and uncertainty, and has many possible solutions (Draper, 1993). As such, the growing issue of global climate change and the daunting task of decarbonizing society seems to be an exemplar of a 21st Century problem that could be approached with a systems thinking framework. Indeed, I argue that systems thinking can be used to help students understand the complex interactions of the complicated world of energy systems in which technology, science, environment, politics, economics, and social milieu intersect.

Therefore, this compilation of high-quality lesson plans has been organized into a systems thinking approach to the energy system. These lessons address the energy system from different levels of magnification. First, students examine the small piece that they play in the energy system in the first two activities, *Energy Efficiency vs. Energy Conservation* and *Classroom Energy Audit.* Then, the students begin connecting these pieces to the larger energy system, such as looking at where our electricity comes from in *Exploring Energy Sources* and *Case Study: Wind Farm in Indiana*. Students also engage with the various scales of the energy system in *Calculating Energy Use and Savings* by calculating energy savings if they change their behaviors, if the whole class changes behaviors, or if the whole school adopts energy saving behaviors. In the *Energy Systems*, students draw connections between energy generation and energy end-use by learning about the economics of energy demand, and how electricity is distributed from the power plants to residential consumers such as themselves. Finally, in the Unit 2 summative assessment, *Installing Solar Panels*, students engage with the complexity of becoming a part of the energy system. The students must first identify what information about the system they need to know, and then evaluate that information to decide if they want to become small-scale energy producers, as well as consumers, by installing solar panels on their homes.

By having students interacting with various pieces of the energy system throughout this curriculum, students will gain a better understanding of the complexity and nonlinearity of the energy system as a whole. Students will have to use critical thinking, quantitative reasoning, design theory, and data analysis skills throughout these activities to interpret the environmental, economic, technological, and sociopolitical issues that exist throughout the highly interdisciplinary energy system. Furthermore, students will be exposed to the relationships such as feedback mechanisms and cause and effect between various actors in the energy system. In doing so, students will gain the autonomy to make decisions and support their opinions on how to move society away from fossil fuels and towards decarbonization.

Connecting the Curriculum to Energy Literacy Research

As discussed in the literature review preceding the curriculum guide, the threat of global climate change and the necessity of moving society towards decarbonization means that energy and energy use will be an important issue for decades to come. However, a lack of knowledge about energy use and the energy system, coupled with psychological barriers to translate knowledge into action, leaves many people feeling unable or unwilling to participate in effective efforts to curtail energy use and transition into a low-carbon energy system (Gifford, 2011). This lack of knowledge about energy use has been well documented (DeWaters & Powers, 2008; NOWCAST, 2005; NEETF, 2002; Gambro & Switzky, 1999; Farhar, 1996; Barrow & Morrisey, 1989), and has inspired researchers to define energy literacy and establish a body of knowledge for how to teach energy literacy in classrooms. This literature review revealed that an effective curriculum to promote energy literacy among high school students must address the cognitive, affective, and behavioral domains, so that students understand what energy is, but also how their attitudes and behaviors contribute to the overall energy system (DeWaters et al., 2007). Furthermore, because there is a disconnect between knowledge and behavioral change, energy literacy curriculums must place an emphasis on energy use in students' lives and how students can make small behavioral changes that are in line with the content knowledge that could last even after the in-school energy unit is complete (Brewer et al., 2013; Dewaters & Powers 2013; McCaffrey & Buhr, 2008; Chess & Johnson, 2007).

This curriculum guide starts with connecting energy issues to students' lives and behaviors, since this was an issue seen in the energy literacy work done by both DeWaters and Powers (2011) in New York State and Lee et al. (2015) in Taiwan. The first task in this curriculum guide is having students think about energy use in their homes and trying to come up with ways they know they can save energy (in *Energy Efficiency vs. Energy Conservation*). In connecting these various energy efficiency and energy conservation behaviors to climate change, students are forced to think about their attitudes and beliefs about why it is important to save energy, and what are the barriers that some people face to enact these energy saving behaviors, which touches on the affective domain. Then, during the *Classroom Energy Audit,* students are able to see where and how energy gets wasted in the classroom that they sit in every day. Furthermore, the at-home energy audit exercise that is given for homework in this activity highlights what students' energy use at home looks like and how much energy their devices use. Next, students look quantitatively at how much energy is used to power the devices and appliances they use each day. They also begin to gain the cognitive knowledge of just how much energy is used when we scale up seemingly small amounts of energy use. Finally, students gain knowledge of how small behavioral changes, such as switching out lightbulbs can make a big impact if everyone did this behavior. This cognitive knowledge is then applied in the *Energy DIY Project* where students must find a way to implement an energy-saving behavior in their own lives. This addresses the disconnect between cognitive knowledge and the behavioral domain cited in the energy literacy literature (Lee et al., 2015; Brewer et al., 2013; DeWaters & Powers, 2011) in that students must try to incorporate this behavior or habit in their daily lives. This project may also contribute to students encouraging others to adopt energy-saving actions since they become invested in their project to save energy. Finally, the unit 1 summative assessment combines all three domain areas in that students must use their cognitive knowledge of energy behaviors to argue for the adoption of a particular energy behavior that the school should implement, and why it would be an effective change. The students must also address the affective domain in discussing the social implications of the school adopting this energy-saving behavior, and why it is important for the school to try and save energy and promote energy savings. Finally, the behavioral domain will be addressed since the students will be arguing for an actual energy saving implementation in the school.

The second unit is similarly grounded in the literature surrounding energy literacy. In *Exploring Energy Sources,* students gain cognitive knowledge about the various types of electricity generation sources that are used in the United States. After learning about the various sources of energy, the students evaluate the environmental implications of different energy sources, which gets at the behavioral domain in terms of having students think about decision-making in the energy realm. Next, as students dive into an examination of wind energy in *Making a Wind Turbine* and *Case Study: Wind Farm in Indiana*, the students learn cognitive knowledge about how turbines work, how to design and build a working turbine, how to calculate energy from wind turbines, how to evaluate various factors affecting turbine output, and what the social, political, and economic factors are in building wind turbines in a given area. After the field trip to the wind farm, the students must decide if they would support wind development in their communities, thus engaging students' affective knowledge. Furthermore, the behavioral domain is also incorporated in that students must be open to new ideas and evaluate the pros and cons of a decision to build wind farm in their area. The *Energy Systems* activity similarly addresses the cognitive domain as students learn about how energy is generated, bought by utility companies, and distributed to end-use customers. The affective domain is also incorporated into this activity as students explore their own ability to choose to "opt in" to using green energy through their utility company. All three domains are addressed in the unit 2 summative assessment, where students need to decide if they would install solar panels on their rooftops to generate some of their own electricity. The students must apply their cognitive knowledge to determine how many solar panels they would need, or how much energy they could generate with a set number of solar panels. Furthermore, they would have to consider the sociopolitical benefits and costs associated with people's attitudes about installing solar panels. Finally, they would use the behavioral domain to evaluate whether solar panels would be a prudent idea for their home, and why one might consider installing solar panels.

Curriculum Applications in Other Courses

An important facet of the energy literacy research suggests that in order for energy topics to be particularly "sticky" for students, they must be exposed to various energy concepts over several years and in several different classroom contexts (Brewer et al., 2013). Therefore, there is value in incorporating various activities within this curriculum guide into different classes and years in school. As such, these activities have been designed to be scaled up or down depending on the level of students and the year in school. Furthermore, this curriculum takes advantage of the interdisciplinary nature of energy so that it can be used in an environmental science class as well as other course disciplines.

For example, *Calculating Energy Use & Savings* is a computational-heavy lesson that could be easily incorporated into a mathematics course in order to demonstrate the relationship between different variables (the relationship between power, energy, and time), as well as to practice unit analysis and conversions. This lesson could also be used in an economics class to talk about budgets and how to save money through various energy behaviors. In a biology class, pieces of the *Classroom Energy Audit* relating to temperature could be used to examine the use of energy in our bodies to regulate temperatures. Depending on how warm or cold the classroom is, students could determine the ideal temperature that the classroom should be kept at, and whether this would use more or less energy to keep the classroom at that temperature. The *Energy DIY Project* could be incorporated into an engineering class where students using engineering and design principles to create an object that will lead to energy saving behaviors. This *DIY* project could also be incorporated into an art class where students explored different mediums and creative spaces with which to create a project artifact. The unit 1 summative assessment, *Adopting Energy Saving Behaviors* could be combined with students' English or speech class to incorporate argumentation and presentation skills learned in these humanities classes.

In the second unit, the *Exploring Energy Sources* activity could be used in a history, civics, or economics class to illustrate where our energy comes from, and why we have historically used the energy sources that we do. Furthermore, A history or civics class could use this activity, coupled with the *Energy Systems* activity, as a case study of society's development based on the fossil fuel dependence established during the Industrial Revolution. The *Energy Systems* activity could also be expanded to address more of the market dynamics within energy markets in an economics class. Using the electricity demand curve, students could learn ways in which electricity markets are structured and regulated to meet this inconsistent demand. A civics class could also explore the local benefits and risks of installing wind turbines in a community by incorporating the *Case Study: Wind Farm in Indiana* field trip and activity. The *Making a Wind Turbine* activity was originally developed to utilize a Maker's Space. If a school has access to this type of resource, students can design their wind turbines using various tools in a Maker's Space such as the 3-D printer or a laser cutter to print existing models of nacelles or to cut different shaped blades for the turbine. Alternatively, a physics or engineering class could incorporate this wind turbine building project to learn more about the factors affecting mechanical energy. Finally, the unit 2 summative assessment, *Installing Solar Panels* could be a joint project with an economics or even a political science class to help students dive more deeply into economic or political facets of individual solar PV installations. Students can do more sophisticated cost-benefit analyses of the payback period of solar panels, or they could look more closely at state policy and incentives that make solar panels more or less desirable in some areas. A chemistry class could look more closely at how solar panels work, and how they panels convert solar radiation into usable electricity.

Connecting the Curriculum to Educational Theory

The accompanying curriculum guide showcases activities found across the internet that both connect to current research on energy literacy and are also grounded in educational theory and research. One of the strengths of this curriculum guide is that it relates to the lives, community, and family of the students, making it a strong example of place-based education (NAAEE, 2015; Smith, 2013; Birmingham & Calabrese Barton, 2013; National Research Council, 2000). For example, the students must think about energy use and behaviors in their own homes, and then must measure energy use at home in *Energy Efficiency versus Energy Conservation* and the homework portion of *Classroom Energy Audit*, respectively. Furthermore, students can use their own measurements and home data to complete various calculations in *Calculating Energy Use and Savings*, which sheds light on how much money is being spent and the amount of carbon dioxide emissions associated with the energy use in the students' homes. In addition, the *Energy DIY Project* offers the opportunity for students to design something that can be used in their own homes and perhaps by other members of their families. The school community is also engaged in both *Calculating Energy Use and Savings,* and especially in the unit 1 summative assessment, *Adopting Energy Saving Behaviors.* In the second unit, the place based educational practices are carried through as the students learn about the energy system in Indiana specifically. The students have the opportunity to visit a nearby wind farm in *Case Study: Wind Farm in Indiana* and consider the viability of solar power for their homes in the unit 2 summative assessment, *Installing Solar Panels*. Both of these units connect student energy behaviors and use to the real-world problem of generating adequate energy to meet demand while also considering the implications for global climate change. By connecting the curriculum to both place and real-world problems, students feel more empowered as actors within their communities to help find solutions for these energy problems (Birmingham & Calabrese Barton, 2013).

In addition, the activities within this curriculum guide promote independent thinking that can lead to effective and responsible action, which according to the North American Association for Environmental Education (NAAEE) is an important principle for excellent environmental education (NAAEE, 2015). Students are encouraged to think independently about taking effective action in several of the discussion portions of the activities including *Energy Efficiency versus Energy Conservation, Classroom Energy Audit, Calculating Energy Use and Savings, Case Study: Wind Farm in Indiana,* and both unit summative assessments. Furthermore, the NAAEE also emphasizes the development of communication skills in excellent environmental education because it allows the learner an opportunity to demonstrate and apply their knowledge (NAAEE, 2015). In both unit summative assessments, *Adopting Energy Saving Behaviors* and *Installing Solar Panels,* the students must apply and communicate their knowledge before school personnel and for their classmates. In the *Energy DIY Project* students have another opportunity to communicate their knowledge that they applied to their energy saving designs.

This curriculum unit also adheres to several principles of how people learn, including activating prior knowledge to help students construct their own meaning and connections between ideas (NAAEE, 2015; National Research Council, 2000). In the first activity, *Energy Efficiency versus Energy Conservation*, students are required to think about what they already know about energy saving behaviors. In *Calculating Energy Use and Savings*, students think back to this first activity, as well as to their *Classroom Energy Audit* homework about where they can best save energy in their house. At the end of *Calculating Energy Use and Savings,* students are able to interact with a visualization of energy quantities in terms of a physical quantity of how much carbon dioxide is released. All of this comes together in the students' *Energy DIY Projects* and in the unit 1 summative assessment. To start unit 2, *Exploring Energy Sources*, students try to guess how most of our electricity is generated. In addition, because of the activity and project-based nature of this curriculum unit, the students are active participants in learning the material, and also engage in metacognitive strategies to assess their own learning process (NAAEE, 2015; National Research Council, 2000). For example, in *Energy Efficiency versus Energy Conservation*, the students are challenged to think about their own attitudes about energy conservation and efficiency, while in *Calculating Energy Use and Savings, Making a Wind Turbine,* and *Case Study: Wind Farm in Indiana*, students reflect on what they found most surprising in these activities. Furthermore, one of the underlying themes in the entire curriculum is addressing misconceptions about energy behaviors and energy usage (Broadbent, 2002; National Research Council, 2000). The first unit addresses and attempts to undo misconceptions related to the difference between energy conservation and energy efficiency, and the relative effectiveness of each. In the second unit, misconceptions about where our energy comes from are dispelled as students learn about different energy sources as well as the larger energy system.

These activities focus on in-depth learning that involves thoughtful problem solving that can transfer to other situations, rather than superficial memorization (National Research Council, 2000). For example, rather than using expository teaching methods to tell students about each of the different types of renewable energy sources, unit two focuses on the two types of renewables that students will likely encounter most often in their everyday lives: wind power and solar power. By having the students explore the most common renewable energy type in Indiana, wind power, over the course of two activities, students will come away with a much richer understanding of how wind energy is generated, and what some of the issues with wind power are. The unit 2 summative assessment presents a very real scenario in which a non-energy expert must figure out what information they need and where to find that information to assess the feasibility of installing solar panels on their roofs. This is a complicated task for students, but it represents the reality that most people are not energy experts and must work with imperfect information while making these important, and expensive, energy decisions. Going through this process of learning what they need to know and making a decision based off of what information they can find, students will gain experience in a type of real-world problem solving that may transfer to other situations in their lives. Finally, the National Research Council's book, *How People Learn* (2000), emphasizes the importance of incorporating assessment into lessons as a form of learning about student learning. Each activity in this curriculum guide has suggested formative assessments tied to the activity, and each summative assessment for the two units can be used to assess whether learning over the unit has occurred.

Possibilities and Barriers for Distributing Quality Curriculums

Once a quality curriculum that can be tied to both educational theory and current research has been developed, the next important step is getting that curriculum into the hands of teachers so that it can be used effectively. In reaching out the authors of the various curricular activities featured in this curriculum guide, I explored how these organizations and research teams connected with educators to disseminate the activities, and what some of the barriers for this dissemination were. One of the most common forms of curriculum exposure and distribution was through offering workshops and professional development seminars for teachers to attend to learn about the curriculums. These workshops are valuable because then teachers can experience the curriculums first-hand and are more likely to find ways to incorporate the various lessons (Swan, personal communication). These workshops are advertised through email blasts, social media, event calendars on the organization's website, flyers sent to school districts, phone calls to certain schools and teachers, and through partnerships with sponsors. School presentations are also an avenue to encourage teachers to attend workshops. In addition to workshops, some organizations hold mini-workshops or set up informational booths at teacher conferences. The National Energy Education Development (NEED) Project also hosts their own conference each summer to promote their materials and help teachers find ways of incorporating energy topics into their curriculums.

Other avenues in which organizations advertise their curriculums is by keeping a database of emails for teachers and school districts. Organizations then can send regular email newsletters, host periodic webinars, and use other websites and curriculum repositories from partners such as "Teach Engineering" and PBS Learning websites. Furthermore, the CLEAN Project develops media kits that they send to state-level teacher organizations to be able to reach more teachers. Governmental organizations such as the National Parks Service rely on press releases since they cannot use traditional advertising, however, they have organization-wide educational programs and portals where individual National Parks can publish their educational materials. Finally, universities such as Clarkson University can utilize grant funding to create graduate fellowship positions to work directly with local teachers to help incorporate information and curriculums into classrooms.

Despite the many ways in which organizations try to reach out to teachers, there are still multiple barriers to dissemination of these materials. One barrier that was cited by multiple organizations was the issue of funding. At Clarkson University, once the grant funding for their program expired, the work on the curriculum stopped and the graduate fellowship outreach program ended. Furthermore, budget constraints limit the number of workshops and professional development opportunities that organizations can hold; and can constrain workshops to only more local areas (rather than having more nationwide workshops). Relatedly, budgets can also restrict the number of people working on various curriculum resources, which can lead to less time being spent on recruitment and workshop planning. Staffing issues can also lead to lower-quality curriculums, and inconsistency in the people working on different projects. For example, the education staff at Shenandoah National Park has been limited to only 1 permanent ranger position, while the rest are seasonal staff that must go through lengthy hiring processes each year. With these fluctuations in staff and having to train new staff members each year, less time can be spent reaching educators. Another issue is whether information sent to schools and distributed through school districts actually gets shared. A representative from the

NEED Project noted that when school districts periodically change their emails, it is hard for an organization to maintain a current database of emails. Finally, one of the biggest barriers is teacher interest and ability to incorporate new curriculums. Several different organizations mentioned that teachers have talked about inflexible curriculums that are set far in advance, making it difficult to bring in new material such as these curriculums. In addition, teachers can often be overloaded with resources and advertisements for various resources, making it difficult for organizations to differentiate their curriculums, and hard for teachers to select the best curriculums to incorporate.

Upon hearing about these strategies and barriers for getting high-quality curriculums into the hands of educators, it is important to evaluate further limitations and opportunities for future work in developing and promoting the best educational resources. Though workshops seem to be a popular method of distributing curriculum resources, these workshops tend to be fairly local, and likely only attract those teachers that are motivated to spend an afternoon learning a specific curriculum. Furthermore, as educators face stringent curriculum requirements and pre-designed classes to meet state standards, there is less room for additional programming such as more robust units on energy that will foster energy literacy. As such, this is opportunity for future work to explore incorporating more energy literacy concepts, including those that address the affective and behavioral domain, into state standards. Furthermore, promoting quality curriculum resources through state standards websites could open up more opportunities for exposure to these documents. Though funding was commonly cited as another barrier for making and distributing high quality curriculums, the use of grant programs, such as the NSF grant used by Clarkson University, or sponsors could be another opportunity for universities and non-profit organizations to allot time and effort to researching and establishing exemplars in research-based curriculums. These programs can then in turn be advertised and offered for free through the universities, and perhaps even the grant programs and sponsors themselves.

Finally, perhaps partnerships with energy organizations could be established so that these energy companies, utilities, and research bodies could also be promoting quality educational resources.

Conclusion

Though this curriculum guide demonstrates that there is a plethora of high-quality resources that promote energy literacy, there is still future work to be done. First, it is important that there is further evaluation of the resources available online to determine which activities can be tied to both educational and energy literacy research, and which activities are of poorer quality. In line with this, there were many resources that were dated, demonstrating that continuous updates must be made to materials as new information, statistics, and data becomes available. This will be particularly important as society begins shifting more and more towards low-carbon energy sources. In addition, I was not able to find any lessons online that specifically dealt with the differences between energy conservation and energy efficiency, and which behaviors were most effective at reducing carbon dioxide emissions. As discussed in the literature review, these are huge misconceptions and these topics must be addressed to correct these misconceptions (Dorji et al., 2015; Attari et al., 2010; Taber & Taylor, 2009; Gardner & Stern, 2008). In doing so, students will be better able to contribute to the "behavioral wedge" for reducing global greenhouse gas emissions (Dietz et al., 2009). Furthermore, it is vitally important to establish studies to measure the effectiveness of these curriculums, and whether students do indeed become more energy literate after working through the curriculum. Though there are many challenges to such long-term efficacy studies, it should absolutely be a goal of educational researchers to work towards a better understanding of how to make educational experiences more "sticky" and impactful. Finally, I think there is also value in a continued exploration of what it means to be energy literate, and what tools students need in order to become productive members of the energy conversation.

In conclusion, this thesis has provided an overview of the literature about what energy literacy is and what it looks like in school curriculums, an introduction to common misconceptions about energy behaviors and use, a two-unit curriculum guide of the best learning activities that seek to address these misconceptions, an analysis of the curriculum guide that ties the activities to educational theory and energy literacy research, and a discussion of some of the methods and barriers for getting these activities into the hands of teachers to be taught in classrooms around the country. Through this effort, it has been clear that there is a strong need for exceptional energy education in high schools, and that these high-quality educational resources exist. The next step is to ensure that these research-based curriculums are the ones that teachers adopt and use in their classrooms to foster a more energy literate generation. By creating this body of work, my goal was to showcase existing resources that specifically address individual energy behaviors and their connection to the larger system of energy use that teachers can bring into their classrooms. These activities have been compiled in a cohesive curriculum that can fit into a high school environmental science class; or can be used individually to bring energy literacy into biology, chemistry, physics, economics, civics, English, art, engineering, or speech classes. As global climate change continues threaten society, and decarbonization becomes a reality for all nations, an interdisciplinary push for an energy literate public will continue to be an important challenge for educators. The curriculum guide provided offers one way for educators to address these issues with sound curricular activities.

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KATHLEEN (KATIE) HALPIN

EDUCATION

Indiana University Bloomington, IN

School of Education December 2018

Master of Secondary Education

Concentration: Science Education

School of Public and Environmental Affairs May 2018

Master of Science in Environmental Science

Concentration: Energy

Cornell University Ithaca, NY

School of Agriculture and Life Sciences May 2011

B.S. in Natural Resources; Minor in Development Sociology; GPA: 3.6

Awards: Graduated Cum Laude with a Distinction in Research

TEACHING EXPERIENCE

Indiana University Bloomington, IN

Teaching Assistant August 2016 – May 2018

- Led outdoor laboratory classes for 7-15 students teaching sampling and analysis techniques in aquatic and terrestrial ecosystems to establish proficiency in applied environmental science
- Mentored students in conducting, analyzing, and presenting original research projects that demonstrate ability in environmental science techniques for future employers
- Evaluated and provided feedback to students on weekly lab reports and research projects to help them achieve proficiency in effective scientific communication

James Cook Languages Prague, Czech Republic

English Language Instructor August 2015 – March 2016

- Taught corporate language courses in English to both individuals and groups of up to eight working professionals
- Tutored students preparing for Cambridge English Language Assessments
- Collaborated with senior teacher through methodological conversation, assessment of best teaching practices, and individualized study plans for specific students and classes
- Designed unique curriculums based on student interests, professional goals, and differing levels of English language mastery to tailor each class to the students' needs

Culver, IN

Culver Academies June 2013 – June 2015

Lead Chemistry Instructor

- Instructed high school chemistry using an intentional and research-based learning cycle
- Established a model for integration between all science disciplines through a curriculum development team within the science department
- Wrote curriculum including: authentic and traditional assessments, course materials, and lesson plans based on new scientific trends and research finding for all introductory chemistry students
- Coordinated a monthly schedule for a team of five other chemistry instructors and mentored new instructors in teaching techniques used in all introductory chemistry classes

Culver Academies Culver, IN
Associate Chemistry Instructor June 2012 – June 2013

- Taught a half-time course load of introductory chemistry to implement my own instructional design with the guidance of a mentor instructor
- Initiated new in-class procedures based on educational research to assist students in utilizing correct learning strategies such as summarizing main ideas and identifying key words
- Evaluated student progress towards established learning goals through authentic assessment
- Communicated electronically and in person with both parents and dormitory counselors to convey evaluation of students' progress towards established learning goals
- Followed a model set forth by mentor instructor in how to effectively plan, communicate expectations, and assess a high school science course
- Wrote reflections on my in-class experiences to identify best teaching practices

OTHER/VOLUNTEER EXPERIENCE

Shenandoah National Park Luray, VA
Climate Change Education Intern June 2017 - August 2017

- Authored a climate change curriculum with 5 lesson plans for local educators
- Organized and ran a 2-day Teacher Workshop for 25 local teachers to learn about Shenandoah National Park and the curriculum offered by the Education Department
- Established content for a climate change webpage for the Shenandoah National Park website

Shedd Aquarium Chicago, IL
Guest Engagement Volunteer June 2013 – August 2015

- Interacted with aquarium guests to answer questions, provide information, give directions, and assist with proper handling of display and touch-tank specimens
- Partnered with aquarium staff in leading a full-time summer camp for 25 school-aged children (ages 7-13) geared towards aquatic education, appreciation, and conservation

Culver Academies Culver, IN
Communications Intern August 2011 – June 2012

- Aided in designing, populating, and launching an award-winning new website
- Maintained all online media for each of the 58 sports teams at Culver Academies
- Created and managed social media accounts such as Facebook pages for major school events
- Edited print and online media including Culver Alumni Magazine and the Culver website

PUBLICATIONS

- **Halpin, K.E.**, B.T. Boscarino, L.G. Rudstam, M.G. Walsh, B.F. Lantry. 2013. Effect of light, prey density, and prey type on the feeding rates of Hemimysis anomala. Hydrobiologia. 720, 101-110.
- Boscarino, B.T., **K.E. Halpin**, L.G. Rudstam, M.G. Walsh, and B.F. Lantry. 2012. Age-specific light preferences and vertical migration patterns of a Great Lakes invertebrate, Hemimysis anomala. Journal of Great Lakes Research. 38, 37-44.

LAB SKILLS

- **Techniques:** field sampling techniques include seining, trawling, electrofishing, setting, retrieving, and processing gill nets, taking secchi disk readings, horizontal and vertical plankton tows, testing water chemistry, taking dissolved oxygen samples, setting up various transects
- **Equipment:** trained in using various types of standard lab equipment